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BULLETIN [illegible] JUNE 1906

Secondary Education

Bulletin 31

NEW YORK STATE SCIENCE TEACHERS ASSOCIATION

PROCEEDINGS OF THE

10th ANNUAL CONFERENCE

Held at Syracuse High School, December 27-29, 1905

PAGE
Officers 1905 3
Officers 1906 3
Council 3
Summary of sessions 3
Summary of action 5
Addresses, papers and discussions 9
A Proposed Biological Survey of New York State: C. W. Dodge 9
Section meetings
Section A—Physics and chemistry
Correlation of Mathematics and Physics: James McMahon 17
The Alternating Current: J. F. Woodhull 27
Section B—Biology
Settled and Unsettled Problems in High School Biology: W. M. Chester [illegible]
Section C—Earth science
Discussion on Syllabus in Physical Geography: C. N. Cobb 40
Nebular and Planetesimal Hypotheses to Account for the Origin of the Earth: T. C. Hopkins [illegible]
Section A—Physics and chemistry
Chemistry in Secondary Schools: W. C. Gray [illegible]
Some Properties of Matter at Low Temperature: J. S. Shearer [illegible]
Some Chemical Experiments to Illustrate Syllabus for 1906: J. F. Woodhull [illegible]
Some Pedagogical Phases of Science Teaching: E. R. Whitney [illegible]
Section B—Biology
The Teaching of Birds from the Economic Standpoint: J. M. Johnson [illegible]
Research and Graduate Work for Teachers of Biology in High Schools: E. P. Bynne [illegible]
Section C—Earth science
Earth Science, History and Culture: E. E. Pearce [illegible]
Section D—Mathematics
Nature of Applied Problems in Algebra: D. E. Smith [illegible]
Algebra in Our Secondary Schools: E. P. Sisson [illegible]
Graphic Methods in Elementary Algebra: William Betz [illegible]
General session [illegible]
Section A—Physics and Chemistry: William Hallock [illegible]
Section B—Biology: A. D. Morrill [illegible]
Section D—Mathematics: E. D. Bue jr [illegible]
Members 1906 [illegible]
Index [illegible]

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NEW YORK STATE EDUCATION DEPARTMENT
1906

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New York State Education Department

Secondary Education

Bulletin 31

NEW YORK STATE SCIENCE TEACHERS ASSOCIATION

PROCEEDINGS OF THE

TENTH ANNUAL CONFERENCE

Held at Syracuse High School, Syracuse, December 27-29, 1905

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G. M. TURNER, *Vice President*, Masten Park High School, Buffalo
J. E. STANNARD, *Secretary-Treasurer*, Owego High School

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J. F. WOODHULL, *President*, Teachers College, New York city
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1909 A. P. BRIGHAM, Colgate University, Hamilton
C. E. HARRIS, East High School, Rochester
HOWARD LYON, Oneonta Normal School
1908 L. V. CASE, Washington Irving High School, Tarrytown
W. T. MORREY, Morris High School, New York city
J. S. SHEARER, Cornell University, Ithaca
1907 A. W. FARNHAM, Oswego Normal School
O. D. CLARK, G. W. Curtis High School, Staten Island
J. E. KIRKWOOD, Syracuse University
1906 G. M. TURNER, Masten Park High School, Buffalo
E. N. PATTEE, Syracuse University
A. G. CLEMENT, Education Department, Albany

SUMMARY OF SESSIONS

WEDNESDAY, DECEMBER 27

2.30 p. m. Opening session at the high school, room 307

Association called to order by PRES. ALBERT PERRY BRIGHAM, Colgate University, Hamilton

1 A Proposed Biological Survey of New York State
CHARLES WRIGHT DODGE, University of Rochester
Discussion opened by
JOHN M. CLARKE, Director of Science and State Museum, Education Department, Albany
2 Proposed Federation of Educational Organizations
GEORGE P. BRISTOL, Cornell University

4 p. m. Section meetings at the high school

Section A—Physics and chemistry. Room 307. HOWARD LYON, Oneonta Normal School, *Chairman*
1 The Correlation of Mathematics and Physics
JAMES McMAHON, Cornell University
2 Demonstration of the Properties and Uses of the Alternating Current
J. F. WOODHULL, Teachers College, Columbia University

Section B—Biology. Room 319. CLARENCE W. HAHN, High School of Commerce, New York city, *Chairman*
1 Settled and Unsettled Problems in High School Biology
WAYLAND M. CHESTER, Colgate University, Hamilton

Section C—Earth science. Room 310. FRANK L. BRYANT, Erasmus Hall High School, Brooklyn, *Chairman*
1 The New Regents Syllabus in Physical Geography
CHARLES N. COBB, Education Department, Albany
W. W. CLENDENIN, Wadleigh High School, New York city
2 The Nebular and Planetesimal Hypotheses to Account for the Origin of the Earth
T. C. HOPKINS, Syracuse University

Section D—Mathematics. Room 307. E. D. ROE JR, Syracuse University, *Chairman*
1 The Correlation of Mathematics and Physics
JAMES McMAHON, Cornell University
(Joint session with Section A)

5.30 p. m. Meeting of the council at headquarters

8 p. m. Union meeting at the high school

SUP'T J. M. THOMPSON, President Academic Principals Association, presiding
Address of welcome
CHANC. JAMES R. DAY, Syracuse University
Address of welcome
SUP'T A. B. BLODGETT, Syracuse Public Schools

Address of welcome
  Sup't J. M. Thompson, President Academic Principals Association

Response and annual address: Needed Educational Legislation
  Sup't F. D. Boynton, President New York State Teachers Association

Address: The Relation of Our Educational System to Present Industrial and Commercial Development
  Howard J. Rogers, First Assistant Commissioner of Education

THURSDAY, DECEMBER 28

9 a. m. Section meetings at the high school

Section A—Physics and chemistry. Room 307. Howard Lyon, Oneonta Normal School, *Chairman*

1 The Teaching of Chemistry in High Schools
  W. C. Geer, Cornell University

2 Properties of Matter at Low Temperatures
  (Demonstration given with the aid of liquid air)
  J. S. Shearer, Cornell University

3 Some Chemical Experiments to Illustrate the New York State Syllabus for 1906
  J. F. Woodhull, Teachers College, Columbia University

4 Observations and Results. Pedagogical Phases of Science Teaching
  E. R. Whitney, Principal of Binghamton High School

5 An Exhibition of Useful Illustrative Apparatus
  In charge of George M. Turner, Masten Park High School, Buffalo

Section B—Biology. Room 319. Clarence W. Hahn, High School of Commerce, New York city, *Chairman*

1 The Teaching of Birds from the Economic Standpoint
  J. M. Johnson, Morris High School, New York city

2 Research and Graduate Work for Teachers of Biology in High Schools
  Esther F. Byrnes, Girls High School, Brooklyn

3 Demonstrations

Section C—Earth science. Room 310. Frank L. Bryant, Erasmus Hall High School, Brooklyn, *Chairman*

1 Earth Science, History and Culture
  Eunice E. Perine, State Normal College, Albany

2 The Laboratory Aspect of Physiography
  William T. Morrey, Morris High School, New York city

3 Report of Committee on Laboratory Exercises in Geography
FRANK L. BRYANT, Erasmus Hall High School
CLARA B. KIRCHWEY, Teachers College, Columbia University
JENNIE T. MARTIN, Buffalo Central High School

Section D—Mathematics. Room 320. E. D. ROE JR, Syracuse University, *Chairman*

1 The Possibilities for More Genuine Applications of Elementary Algebra
DAVID EUGENE SMITH, Columbia University

2 The Purpose and Method of Algebraic Study in our Secondary Schools
E. P. SISSON, Colgate Academy, Hamilton

3 Graphical Methods in Elementary Algebra
WILLIAM BETZ, East High School, Rochester

2 p. m. General session. Room 307

1 Announcement of committees by the president

2 The present sessions mark the completion of 10 years of work by this association. In recognition of this fact representatives of the several sections will offer some review of progress and propose an outlook upon the needs and work that lie before us.

Section A.	WILLIAM HALLOCK, Columbia University
Section B.	A. D. MORRILL, Hamilton College
Section C.	C. T. McFARLANE, Brockport Normal School
Section D.	E. D. ROE JR, Syracuse University

3.30 p. m. Meeting of the council at the high school

8 p. m. Union meeting at the high school

SUP'T F. D. BOYNTON, President of the State Teachers Association, presiding

Address
PRES. JACOB GOULD SCHURMAN, Cornell University

9.30 p. m. Fraternity and college reunions

FRIDAY, DECEMBER 29

9.30 a. m. Section meetings

The sections will meet for the election of section officers and for miscellaneous business.

10 a. m. General session

1 Report of treasurer
2 Report of auditing committee

3 Report of nominating committee, election of officers, announcement of place of next meeting
4 Necrology
5 Reports of standing committees and delegates
6 Miscellaneous business
7 Adjournment

SUMMARY OF ACTION

Biological Survey of New York State. After discussion of Professor Dodge's paper on the proposed biological survey of New York State the following action was taken.

Moved as the sense of the Science Teachers Association that the Board of Regents be memorialized to take such steps as may be necessary to organize to make effective a distinctively biological survey of the State of New York. *Carried*

The following members were appointed on a committee to aid in carrying out the project of the biological survey.

C. W. Dodge, *Chairman*, University of Rochester
C. W. Hargitt, Syracuse University
C. W. Hahn, High School of Commerce, New York city

Federation. After a discussion of Professor Bristol's talk on federation it was resolved:

1 That the State Science Teachers Association favors a federation of the different teachers organizations of the State.
2 That the executive council be made a committee with power to act in the matter of federation.

The council took the following action.

Moved, That the retiring president of the association select from the council two members to constitute with the incoming president a committee to meet with representatives of the other societies and confer on the matter of affiliation and draw up a tentative plan, this plan to be reported to the council for action next year. *Carried*

The committee as selected:

John F. Woodhull, *Chairman*, Teachers College, Columbia University
George M. Turner, Masten Park High School, Buffalo
Howard Lyon, Oneonta Normal School

Metric system. *Moved*, That the New York State Science Teachers Association heartily favors the passage of the bill pending before Congress favoring the adoption of the metric system. *Carried*

Treasurer's report

Summary as per books and vouchers on file for year ending Dec. 29, 1905

Receipts

Jan. 13, 1905 Check from P. F. Piper	$38 03
Dec. 29, 1905 Dues to date	165 ..
Total	$203 03

Expenditures

Dec. 29, 1905 Total to date	$110 60
Balance on hand	92 43
	$203 03

Auditing committee. We, the undersigned, regularly appointed auditing committee of the New York State Science Teachers Association have examined the report and accounts of Treasurer Stannard and desire to report that we find them correct in every detail.

E. R. Whitney
E. P. Sisson

December 29, 1905
Report accepted

Section officers for 1906

Section A—Physics and chemistry

Chairman, C. E. Harris,
East High School, Rochester

Section B—Biology

Chairman, Esther Byrnes,
Girls High School, Brooklyn
Secretary, W. M. Chester,
Colgate Academy, Hamilton

Section C—Earth science

Chairman, T. C. Hopkins,
Syracuse University
Secretary, Jennie T. Martin,
Central High School, Buffalo

Section D—Mathematics

Chairman, William Betz,
East High School, Rochester
Secretary, F. L. Lamson,
University of Rochester

Reports of committees

Second year physics. No report. Committee continued.

Laboratory course in physiology. Mr C. N. Cobb reported that the work of the committee was made the basis for work in the 1905 Syllabus.

Report accepted and committee discharged.

Joint committee on teaching physiology. The following report was presented by Prof. I. P. Bishop.

A conference of delegates from the Associated Academic Principals, the Council of Grammar School Principals, the State Teachers Association, and the New York State Science Teachers Association met at the Vanderbilt Hotel, Syracuse, December 28, 1905. At this meeting it was decided by unanimous vote to recommend to the organizations represented that they take action looking toward changes in the *Ainsworth School Physiology* in certain particulars among which are the following:

1 Textbooks should not be obligatory below the sixth grade.
2 The clause regarding the grading of text should be modified to conform to the above change.
3 The restriction as to the number of pages to be devoted to alcohol and narcotics in all textbooks should be removed or modified.
4 The requirement that the effects of alcohol and narcotics should be taught in connection with each topic should be removed or modified.
5 The choice of textbooks should be unrestricted by law.

The conference also recommends that a joint committee of the organizations represented be appointed to draft an act embodying the above changes and to secure the necessary legislation. This committee to report at the next holiday meeting.

Report adopted, and Professor Bishop was appointed as our representative to confer with joint committee of the different organizations to carry out the suggestion given in the last part of the report.

ADDRESSES, PAPERS AND DISCUSSIONS

Wednesday afternoon, December 27

A PROPOSED BIOLOGICAL SURVEY OF NEW YORK STATE

BY CHARLES WRIGHT DODGE, UNIVERSITY OF ROCHESTER

In 1835, upon the motion of Charles P. Clinch, a representative from New York city, the Assembly passed a resolution directing the Secretary of State to report to the Legislature at its next session the most feasible method of obtaining a complete geological survey of the State, including a scientific account of the rocks and soils, a list of mineralogic, zoologic and botanic productions, and the collection and preservation of specimens of the same, with an estimate of the expense of the undertaking. The report was submitted in January 1836, by John A. Dix, then Secretary of State, and the act of April 15, 1836, authorized the project, the Assembly unanimously voting an appropriation of $104,000 for the enterprise. In 1842, the expenditure of the additional sum of $26,000 was authorized. Governor Marcy arranged the plan of the survey and distributed the several departments of the work among a corps of specialists. The report of the survey was published between 1842 and 1854 in 17 huge quarto volumes with numerous plates, many of them being colored, under the title of the *Natural History of New York.* Five volumes were devoted to zoology, two to botany, one to mineralogy, four to geology, and five to agriculture. The survey has since been continued along geologic and paleontologic lines by James Hall and assistants, and by his successor John M. Clarke, the reports up to the present time filling eight large quartos and many octavos. The various specimens collected were used in part to constitute the State Museum, some part of the remainder being distributed among the collegiate institutions of the State.

In the survey of 1836, many things which we now recognize as of vast scientific and economic importance received no attention whatever and it is largely to remedy this deficiency and to make our knowledge of the animals and plants of the State more extensive and complete that a new survey is proposed.

In the original survey the larger animal forms from the mammals down to the crustaceans were collected, identified and described but the lower invertebrates were ignored. We have since come to appreciate the great importance of worms and entomostracans, for example, as food for fishes, and of protozoans in the sanitation of drinking water. The breeding habits and economic value of mammals, birds, reptiles, fishes, mollusks, insects and crustaceans were not investigated, but now we recognize the importance of these various animals as sources of food or clothing, or as beneficent or harmful agents in agriculture, horticulture, or fish culture, in the rearing of domestic animals and in hygiene.

The botanic work of the survey was mainly the collection and description of the higher plants, the fungi, lichens and algae not being taken into account. The importance of these forms in furnishing material for many of the strictly scientific problems of biology renders it highly desirable that systematic efforts be made to increase our knowledge of these plants, their distribution, mode of life and economic effects in agriculture, gardening, forestry, fish culture, and the management of water supplies.

Since the establishment of the office of State Botanist in 1867 and of State Entomologist in 1882 reports have annually been made by these officers showing that much valuable work has been accomplished, by the former in noting newly discovered species and especially in describing and illustrating the edible and poisonous fungi of the State, and by the latter in investigations mainly upon insects of economic importance.

Then, too, lists containing more or less descriptive matter have been published by the State Museum or are in preparation on the mammals, birds, fishes, reptiles and batrachians, mollusks, and crustaceans, but the most of these need revision and amplification, and can not be made complete until more material has been collected and extensive observations made. The lower plants and animals have as yet received practically no attention; our knowledge of the higher forms is exceedingly incomplete, and of the great majority of aquatic organisms we know little or nothing.

Since the completion of our State Survey important work of the kind contemplated has been accomplished in other countries and states by individuals working independently, or under the auspices of institutions, or for government purposes. Reference will be made in the present instance only to what has been done in the investigation of inland waters. In a paper published by Prof. H. B. Ward in *Science* a few years ago he showed that the most of the countries of western Europe have each one or more permanent laboratories for the study of fresh-water organisms. Nearly 20 years ago Professor Fritsch, of the University of Prague, established a laboratory on the Black lake, a small body of water in the Bohemian forest. Previous to this time various investigators had worked in temporary quarters both in the United States and abroad, but no one before Fritsch seems to have had a building specially constructed for the purpose. A similar laboratory is in operation in Finland, and another near Moscow in Russia. Hungary has a station at Lake Balaton, one of the largest bodies of fresh water in Europe. In France there is a lacustrine laboratory near Clermont-Ferrand. The most famous of all such laboratories is at Lake Ploen in Holstein under the direction of Dr Zacharias. Each year since its establishment in 1891 a volume of researches has been published by the station and its position has now become sufficiently well assured to warrant the publication of a journal to be issued at regular intervals and to be devoted exclusively to limnobiology. Germany has also two other stations of lesser renown and one has been established in England. The most famous investigator of the biology of fresh water is unquestionably Professor Rorel, of the University of Lausanne. His studies of Lake Geneva, three volumes of which have already appeared, furnish a guide to such work in all its branches.

In the United States permanent or summer stations are maintained on Lake Mendota, in Wisconsin; at Chautauqua lake, in New York State; at Gull lake, in Minnesota; on Lake Erie at Sandusky and at Put-in-Bay in Ohio; at Turkey lake, in Indiana; and at Havana, in Illinois. Some of these stations are mainly for teaching, as that at Chautauqua lake; others are for research exclusively, as the station of the United States Fish Commission at Put-in-Bay, Ohio; and others for both teaching and investigation, as those maintained by the Universities of Ohio, Indiana, Illinois and Wisconsin, while Massachusetts has a laboratory at Lawrence devoted solely to the study of filtration and the biology of drinking water. In Illinois, Indiana, Michigan, Minnesota and Connecticut biological surveys are in progress at the present time. In New York no systematic examination of the inland waters has ever been made. It is highly probable that a biological survey of New York will yield most valuable scientific results. Its surface is more diversified than that of any other state in the Union. Its area is over 49,000 square miles. Its borders in part are outlined by the shores of two of the Great Lakes, by one of the largest rivers of the world, and by the Atlantic ocean. Within its limits are lakes and ponds of every description, fresh-water, brackish water and saline; a unique system of glacial lakes whose fauna is thought to have an intimate relation to that of the sea with which the lakes were at one time connected; shallow lakes and lakes so deep that they are popularly reputed to have no bottom; lakes situated at high as well as lakes at low altitudes; lakes with and lakes without outlets; lakes whose various waters are of widely different chemical composition; isolated lakes and lakes connected in chains or systems; lakes fed by rivers or smaller streams as well as lakes whose water comes from springs. Its rivers are almost as varied as its lakes. Some of the systems empty into the Great Lakes while others flow to the sea. The great tidal Hudson offers every degree of salinity. In the Niagara river with its falls and gorge, organisms live under conditions scarcely paralleled in the world. Mineral springs in great variety offer nearly unexplored fields for investigation. A great canal which traverses the State from east to west furnishes a habitat unlike that found anywhere else in the United States. Immense swamps and marshes thousands of acres in extent, harbor organisms concerning which there is much to be learned. The islands in the

Great Lakes, in the inland lakes, and in the ocean offer inviting fields for exploration.

Its surface extending 300 miles from north to south and 326 miles from east to west presents altitudes from sea level to over 5000 feet, including many of the highest peaks east of the Rocky mountains. There are two mountain regions, one in the northeastern and one in the southeastern part of the State. Caves and subterranean passages in considerable number are to be found whose biologic conditions are unknown. The condition of the land varies from that of the thickly populated cities to that of the unexplored forests; land which has been occupied and settled for nearly three centuries and land which has but recently been cleared by the settler. Every variety of soil is represented, sand, clay, and rock, and the climatic conditions are such that in certain parts of the State plants and animals flourish which are characteristic of the flora and fauna of the Carolinas. No fewer than three life zones, as they are called, are represented in New York, the boreal, the transition and the upper austral, each zone being one of the seven transcontinental belts characterized by a natural grouping or distribution of plants and animals. In respect to number of such zones New York is surpassed by but two of the states east of the Rocky mountains, viz, North and South Carolina; most states having not more than two zones. While the transition zone occupies the greater part of the State, the boreal is represented in the Adirondacks, the Catskills, and in the highlands of the southwestern section. The austral zone sends a long arm up the valley of the Hudson river to Lake George, while another extension from the Mississippi valley region reaches from Buffalo to Syracuse extending back from the shores of Lake Ontario for a distance of about 30 miles. The extent and variety of our fauna and flora then are unusual.

It is therefore proposed that a survey be inaugurated in accordance with the following tentative suggestions:

Its object shall be (1) to study the biology of the fauna and flora of the State, especially of the aquatic organisms, including their structure, habits, food, distribution, variations, adaptations, ecologic relations and economic importance; (2) to investigate such sanitary problems of a biological nature as may arise concerning the lake and river waters used by the cities, villages and towns of the State; (3) to study lakes with reference to the propagation of fish.

In its organization the survey should properly be under the control of the State Museum, and the members of the survey should be equipped by training and experience to serve in field, museum and laboratory; the regular staff performing the most of the work, specialists being engaged only for the purpose of monographing certain groups of organisms or for some particular service of like nature. If the survey could be recruited from the faculties of the universities and colleges of the State, competent investigators would be enlisted, a wider interest in the work aroused, and much expense saved for apparatus, field equipment, books etc. The most important work would fall to the field parties, and each of these ought to be in charge of a biologist of sufficiently wide interests and attainments to be able to direct investigation along both botanic and zoologic lines, that is to supervise the study of the special problems assigned to his assistants while he at the same time keeps the general work of the party progressing. As assistants it would seem desirable to engage as far as feasible, the instructors and advanced students in biology in the colleges and universities, as well as competent high school teachers. Many would be glad of the opportunity to do the work required in return for the experience gained. The field work would necessarily include the collection, not only of biological facts and specimens, but of physiographic, chemical and meteorologic data as well.

The material collected, not only specimens, but also notes, drawings and photographs, should belong to the State Museum and should be added to that already deposited there, and all interesting specimens should be displayed in proper exhibition cases. In addition to the skins of birds and mammals, and the bodies of animals which are seen in conventional museums, there should be collected as many things as possible that show facts about the habits and mode of life of organisms such as specimens of male, female, and young of each kind of animal, the larval forms, eggs, egg cases and nests, parasitic and pathologic conditions, examples of the depredations committed by noxious forms, the vegetative and the reproductive stages of plants in cases where these are unlike or markedly different, as in many algae and fungi. If any material can be obtained in sufficient quantity small collections, with the specimens properly named, should be distributed to the schools throughout the State for use in teaching the biologic sciences. If injurious forms, like the gipsy moth in its various stages for example, could be made generally known, especially in the lower schools, much harm to the State at large could probably be avoided by putting people on their guard against an invasion of pests which is certain to come within a short time.

The reports of the survey should be published in suitable form using the best class of illustrations where any at all are required. These publications should be distributed liberally throughout the State, especially to schools, and the district schools and those in small towns ought to be remembered in the distribution. Groups of popular interest should be treated in such manner as to attract the general reader, and the identification of species made as easy as possible by the use of analytic keys in which technical terms are avoided to as great an extent as is consistent with accuracy.

The cost of the survey would depend upon the nature and extent of the work undertaken. In Illinois the annual expense at present is about $10,000, and in Minnesota it is estimated at $10,000 to $20,000. In each of these states the work is in the hands of a staff of trained investigators who are paid for their services.

It is now 50 to 60 years since the different biologic branches of the original Natural History Survey were completed. In that time not only has the territory covered undergone great changes due to settlement of the land, destruction of the forests, drying up and filling in of water courses, extension of agricultural and manufacturing operations, increase of population of cities, towns and villages, but our knowledge of plants and animals has also grown. With increasing knowledge a multitude of problems has arisen in morphology, physiology, distribution, variation, adaptation and evolution, and the scientific point of view with respect to organic nature has changed entirely from the position it occupied at the time the survey was made. The object of the proposed survey is not so much merely to make additions to the list of plants and animals already known to live within the borders of the State as it is to increase our knowledge of the habits and the biological and economic importance of these organisms. It is most essential, therefore, that if the State of New York wishes to retain a leading position in educational and scientific matters it should do more than it is now doing in the study of its fauna and flora.

Discussion

JOHN M. CLARKE, DIRECTOR OF SCIENCE DIVISION, STATE EDUCATION DEPARTMENT

The New York State Museum, in the present organization of the Education Department, is the depository of the scientific collections of the State; the Division of Science, the staff of scientific workers.

The institution, during its history of 50 years, has been preeminently a museum of geology, and though biological investigations have long been prosecuted under its auspices yet these have been undeniably overshadowed. It has seemed proper to make a claim upon the State for more equable progress in these sciences, and the proposition to initiate a careful study of our inland waters, to be principally biological without overlooking any contributory data, presented itself to my judgment as specially promising of fruitful results to New York State science. The plan commended itself heartily, not alone to several of our best known biologists but to the Commissioner of Education and the Board of Regents of the University. The Governor signified his belief that the plan was timely and proper and the appropriations committees of both houses took no serious exception to it. The State has two commissions whose work involves certain executive functions in biological science—one the Forest, Fish and Game Commission, the other the Health Commission. The former opposed no obstacles to the proposition and the latter none which were not satisfactorily removed. Nevertheless any new plan for increased State aid to scientific work at Albany will not race through the legislative chambers; it is likely to be jolted, kept long on trial, its progress apt to be slow and halting. It has to stand aside for civic measures and exigent appropriations.

But progress has been made. We have asked for a modest appropriation and have a reasonable confidence that this will be granted. The general plan of the work has taken very much the expression which I presume has been set forth in Professor Dodge's paper and the indorsement by the Science Teachers Association of the project as one promising large results to the people both in its economic and purely scientific returns will be helpful in bringing the effort to a conclusion. If such indorsement can be formally expressed so much the better.

In several departments of scientific research New York has been the leader among the states, earliest on the ground, breaking a way where others might follow, most continuous and persistent in the maintenance of these efforts; but in this biological study of her waters she has lagged behind some of the others though none of them presents such an attractive diversity of problems. This is not to her credit.

It may be well for me to say plainly that the Director of the Science Division does not propose to personally conduct a biological survey. His duties are too diverse, his personal scientific proclivities happen to lie in another direction but he does propose to give this work, when provided for, such executive supervision and encouragement as lies in his power.

SECTION MEETINGS

Wednesday afternoon, December 27

Section A—PHYSICS AND CHEMISTRY

THE CORRELATION OF MATHEMATICS AND PHYSICS

BY JAMES McMAHON, CORNELL UNIVERSITY

This paper is intended to open a discussion on the question as to what degree of correlation of the instruction in mathematics and physics is most desirable and feasible in the secondary schools and colleges of this State. I say what degree, for the word correlation is very elastic in its meaning. As I understand it, two subjects are said to be taught in correlation when they are so presented that each derives more or less benefit from the other, and confers certain favors in return. This correlation may be close and systematic, or it may be loose and incidental, in varying degrees. The closest degree of correlation, advocated by some enthusiasts, is hardly distinguishable from a complete fusion or unification, in which certain parts of mathematics and physics are taught by the same teacher, at the same time, as a single dovetailed course. The next lower degree is when the subjects are taught by the same teacher at different hours, with systematic cross references from one subject to the other. In the still looser degrees of correlation, there are different instructors with more or less sympathetic relations and mutual understanding. In all our institutions of learning there is of course some degree of correlation, the mathematics being taught with some reference to the needs of allied departments, and some physical illustrations being introduced to throw light on certain mathematical processes. This practice has been increasing in recent years, and the question has arisen whether it should not be erected into a general pedagogic principle and carried out more systematically. In this era of pedagogic experiments we in New York are perhaps fortunately situated in being under the influence of the conservative atmosphere of the East, while we are open to radical impulses from the West. Without being carried off our feet, we can watch with sympathetic interest the thoroughgoing pedagogic experiments now being made by some of our brethren in the Central States. I presume that most of you have seen the admirable report of the committee on the correlation of mathematics and physics in the secondary schools, published as an appendix to the proceedings of the Central Association of Science and Mathematics Teachers, and also published in separate pamphlet form. It seems to me that that report says everything that need be said with regard to the general principles on which any valuable correlation should be based; and ample material is appended for carrying out the principles and methods to any desired extent. The important question for us today is how the methods are working out in the classrooms where they are being tested. The experience of some well known teachers who have actually tried various degrees and methods of correlation have been published from time to time in educational journals. They report varying degrees of success; and I can not open this discussion better than by quoting the words of some teachers who have placed themselves on record in this way for the benefit of their fellows. I do not here quote mere theoretic statements of what some people think other people should or should not do, but results of actual experience by the writers themselves.

The most enthusiastic advocate of close correlation in secondary school work is Miss Edith Long of the High School, Lincoln, Nebraska, who speaks from an experience of several years. I will not diminish the force or grace of her words by attempting any abstract of her paper; and in order that those who have not seen the article may catch something of her spirit, I shall quote at considerable length. In the *Educational Review* for October 1902, Miss Long writes in part as follows:

> This school goes further than the correlation of algebra and geometry; it has introduced a large amount of science—physics and physical geography—for the sake of a broader concrete basis for the algebra, and more interesting application of the geometry. In order that a clear understanding may be had of the feasibility of this plan, it will be necessary to describe another branch of the course of study. One of the required subjects for the first year student is a course in what is termed "elementary science." It consists chiefly of recitation and laboratory experiments in the common elementary physical laws with which the child comes in daily contact. The study excites the keenest interest, and algebra based on the concrete notion of quantity, both positive and negative, has a life and meaning unattainable under the method of abstract—to the student meaningless—reasoning with symbols and rules. Indeed the clear comprehension of comparison of quantity which even the ninth grade student acquires under the development of mathematics on a concrete basis is surprising. By means of material from the laboratory of actual measurement and weight, sustained by geometric intuitions of distances, areas, and angles, both positive and negative, algebraic principles are firmly fixed in the mind—the specific cases gradually giving way to symbols of general quantitative expression. For example equation work is taught in connection with experiments on the

balances. At first all problems leading to equations are taken from actual experiments made; then as the pupil begins to feel the tediousness and uselessness of specific numbers of grams, decigrams, etc., in carrying out his thought, he is led to introduce general expressions—in fact, many pupils will attempt this without suggestion on the part of the teacher and write w for weight of some substance, or c for number of centigrams etc., or l for length of lines, a for size of angles; while under the direction of the teacher a more thorough comprehension of general quantitative expression is obtained than can be obtained under any other method of presentation. Furthermore by geometric relations of magnitude and by laboratory studies of such laws as that of the lever and Boyle's law, the student reaches an understanding of ratio both direct and inverse, clearer to a degree than is ever possible under the isolated teaching of algebra. Positive and negative quantities become a reality through geometric and physical examples. Solution by rule is unnatural to this method of teaching and is strictly guarded against . . . Throughout the entire first year the three studies, algebra, geometry, and physics are kept together—the latter supplementing the former with concrete material, the former furnishing the solution of problems drawn from the experiments of the latter and leading to generalizations of results. The reasoning is similar if not the same in all, which fact is kept constantly before the student.

During the second year when equation work is strongest, the geometry and physics furnish a body of material which can be utilized to create the greatest enthusiasm and interest in the subject. To add to this, the more elementary ideas of trigonometry are introduced in connection with ratio and proportion and similar triangles thus opening up another line of practical applications.

The objection has been offered to this plan of teaching mathematics that it will require too much time. This is not true. The mathematics is completed in less time than is required by other schools in the state, or than was formerly required in this school under the single study method, while a far greater degree of thoroughness and insight into the subject is obtained.

The truth of this statement will easily impress itself upon any one who stops to consider that, instead of being shot through the algebra in a year and geometry in a year and a half, without any clear notion as to the use of either, the student spends in reality two and a half years on each. The principles are inculcated in such a way that they can not be forgotten, while the application of mathematics to physics is clearly understood, and the knowledge of physical laws is utilized to stimulate the student in the pursuit of that branch of learning which alone embodies indisputable truth.

In partial contrast with Miss Long's experience, I shall next quote from a teacher situated a little farther east, Miss Mabel Sykes of South Chicago High School, who advocates a less close degree of correlation. At the 18th annual conference of the academies and high schools in relations with the University of Chicago, November 1904, (reported in *The School Review* January 1905), Miss Sykes spoke in part as follows:

> Dr Tompkins' remark "Push your [own] subject to its utmost, and you do all the correlating necessary" seems to me to define the legitimate limits of correlation, and to apply both to the teacher of physics and chemistry and to the teacher of algebra and geometry. If a problem involves a technical knowledge of another subject that can not be given by a few words of explanation, that problem and the algebra necessary to solve it belongs to that other subject, and the teacher [of that subject] has no right to object to a review of the necessary mathematics. On the other hand it seems to me that a training in certain applications of algebra is a vital part of the algebraic work. Among the most important of such applications are problems involving time, rate, and distance, problems involving mensuration or arithmetical relations with which the pupil is familiar. The manipulation of formulas from physics and arithmetic, so as to solve for the various letters involved, seems to come under the same head. If, as has been suggested, the pupil is early introduced to the various kinds of equations, consideration of any one kind of problem is a comparatively easy matter. Take, for example, the questions involving time, rate, and distance. After the relations have been thoroughly discussed, the different kinds of problems can be taken up, the easiest first, without regard to the nature of the equations produced. There are cases of one body meeting another, or of one body overtaking another, and cases involving the resultant of two forces. All the cases must be thoroughly discussed before more complicated problems are given.
>
> One of the most serious problems in algebra teaching has long been how to give algebra a meaning to a class of beginners. There have been attempts made to solve this problem by the introduction of graphs and elementary physics experiments. Because these things give to us concrete illustrations of abstract ideas, we have assumed that they do to the child. As a matter of fact they are as surely outside of his experience as the mathematics however concrete they may be in themselves. It may be a simpler matter to enlarge the experience so as to take in the things desired for illustration than it is to take in the algebra. . .But a roundabout connection has to be established between the child's life and the illustration, and then between the illustration and the subject in hand . . . By means of arithmetic handled judiciously we may establish a direct and not a roundabout connection between algebra and the child's life.

The next teacher whose experience I quote is also a resident of Chicago, but a much more thoroughgoing advocate of the use of the laboratory method, as a sound pedagogic principle. Prof. G. W. Myers of the College of Education of the University of Chicago, writing in the *School Review*, 1904, says:

I give a few practical examples such as I have actually used with high school classes with what seemed to me a sufficient measure of success to justify doing more of it myself and commending it to those concerned in the practical problem of unifying the mathematics and science in the secondary curriculum.

A method of handling experimental data in a mathematical class may be exemplified by the study of friction. The data and results of such a study are given in the table for the friction of pine against pine . . . [Here follows a table and an explanation of the method of deducing the law of friction from the numerical data by a method of successive approximation] . . . There is little of the algebraic technic from the beginning of algebra to the solution of simultaneous linear equations that is not called for in this work, though, at every step, it appeals to the student as subsidiary—*incidental*, if you please, but not *accidental*—to an appreciably valuable main purpose. Nor is the arithmetic ignored. The student is learning where "to put the point," for he is handling decimals throughout.

Graphical work might profitably come in here in either of two ways: (1) the student might represent geometrically the final law; (2) he might have plotted the observations, and, with the aid of a taut string, have drawn the mean line and derived the law independently from the picture, and then have compared the law graphically derived, with that derived algebraically and arithmetically as above. But I would not advise using the graph of observations, or of equations, otherwise than as a means to a better understanding of some law or truth which is really illumined by it. I doubt the wisdom of using the graph for its own sake much before the early college years. I am convinced of the wisdom of using it *as a means* to lighting up difficult matters even before the high school.

Professor Myers then goes on to mention the law of the pendulum, the loaded steel spring, the inclined plane, Boyle's law, as furnishing excellent material for the study of algebraic relations in connection with the laboratory method. He is decidedly favorable to this method as a pedagogic principle.

Our next witness is much more conservative, which may be partly due to the fact that he is situated considerably east of Chicago. Mr F. T. Jones of University School, Cleveland, reports his experience in using the outline of laboratory experiments in plane geometry which was prepared by Professors Plant and Bishop of Bradley Institute, Chicago, and was published as an appendix to the report of the committee on correlation mentioned above. Writing in *School Science and Mathematics*, June 1905, Mr Jones says in part:

Using the outline as a basis, I tried physical laboratory experiments with a class of boys in geometry corresponding to second year high school pupils. Contrary to my expectation and desire the attempt to use these experiments could not be considered a success. Among the experiments tried were the following: (1) comparison of inch and centimeter, (2) law of reflection, (3) center of gravity of a triangle, (4) law of refraction. After spending some time on such experiments with indifferent success I changed my mode of operation and introduced the use of squared or cross-section paper, plotting of straight lines, circles, ellipses, solution of simple simultaneous equations of first and second degree, finding areas by counting squares, and deducing rules for computing areas. This was successful in the cardinal features which any proper experiment should possess: (1) it stimulated thought; (2) compelled scientific observation and reasoning; (3) compelled accurate and careful work; (4) was not too difficult; (5) taught definite facts; (6) was intimately connected with classroom work . . . As far as can be judged from a single year's trial, physics laboratory experiments performed by the class in connection with plane geometry were not especially helpful, but occasional lecture experiments which had a direct mathematical application and which gave quite exact results may be of great assistance. . .in enlivening and explaining the subject. Also from the single year's trial it seems that experiments in plotting curves and finding areas graphically are well worth doing in connection either with geometry or algebra. Where used, I can see no reason for any radical departure from the way in which algebra is introduced. As to the introduction of the subject of geometry, the method of observation and experiment can, and I believe should be extensively used. To put off its introduction until the first or second high school year (ninth or tenth grade) is, however, too late to realize the most reliable results. . . An improvement in the quality of problems in geometry and algebra is much to be desired; but to add concreteness and to make them really practical some very few physical notions are necessary. Among these may be mentioned specific gravity, vectors (parallelogram of forces), velocity . . . The panacea for all our difficulties does not lie in a laboratory method in mathematics or in any other method, but in a steady systematizing of our mathematics and associated courses so that each shall support the other. There is also necessary a growth of true scientific spirit among the teaching force that the thinking power of the pupils may develop under the stimulus of observation and experiment.

Having listened to the varied experiences of these earnest and representative teachers we may stop to notice a few salient points. Among diversities of conditions and methods they are all animated by the same noble spirit; they keep the end and aim of all instruction steadily in view—the making of clear thinkers, enlightened citizens, good men, of disciplined and soldierly temper. Their more or less outspoken utilitarianism is largely on the surface. They begin with the familiar and real, but their main purpose is intellectual and ideal. The student is at first beguiled with the allurements of interesting familiar things, that he may gradually learn to run with patience the long race which finds its crown and chief reward in the love of intellectual things for their own sake.

Again there is no mere paper correlation carried out in a wooden way; it is tentative, it is elastic, it is human. If I may adapt a phrase from the Gospel, the system is for the child, and not the child for the system. It is equally true that the system is for the teacher; for it is being gradually adapted to himself, as well as to his material, and the atmosphere in which he works.

Moreover these teachers do not seem to have been made afraid by any terror that walketh by noonday or by night, in the shape of the school superintendent, or the college entrance examiner. They appear to have faith in the essentially human spirit of these functionaries, that they can be trusted to recognize real and vital and fruitful knowledge wherever they may meet it, even though not clothed in traditional forms. In this generous faith I am convinced they will not be disappointed.

This leads me to give a few very instructive quotations showing the attitude of some institutions of collegiate grade towards the problem of close correlation.

A very close degree of correlation has been in practice for some years at Bradley Institute, Chicago. Prof. F. L. Bishop describes it in *School Science* for March 1905, as follows:

> From the point of view of the physicist the work of correlation at Bradley Institute commenced some six years ago when the mathematical department discarded the algebras then in use, and made out an outline one which used extensively the graph and introduced a large number of physical problems. These problems were selected in what appears to me now an almost ideal manner. The physical department furnished a list of all the typical equations used in elementary physics, and later a series of problems which covered every type of equation. The mathematical department then selected from these, and added many others which appeared especially well adapted to students in elementary algebra. From simple problems to simple apparatus was only a step . . . Two years ago the mathematical laboratory for work in concrete geometry was established . . . Some of the experiments were taken directly from the physics, while others were original and not ordinarily given at the present time in the elementary physics. Great care was taken in the selection of these experiments to include only in general those that have a geometrical proof, thus enabling the student to obtain a very clear comprehension of the practical applications of his geometry. The second object that was aimed at was the selection of experiments which required only the simplest form of apparatus . . . It is not the aim of this laboratory course to teach the student manipulation of complicated apparatus.

It was early recognized that it would be impossible to have a close correlation between the physics and mathematics unless the instructors were familiar with the work of both departments. For this reason one mathematical instructor taught three fourths of his time in mathematics and one fourth in physics, while one of the physics instructors gave three fourths of his time to physics and one fourth to mathematics, i. e. the physics instructor had one class in geometry or algebra and the rest of his time in physics. This also furnished a bond of interest between the two departments, in that each knew the aims and objects of the other.

The results obtained from this arrangement can not be overestimated. It seems to me doubtful if as much could have been accomplished in any other way, at least it would have required a much longer time. Another feature which contributed materially to the success of this correlation was the introduction three years ago of a course in physiography, which is taken by all students during the first quarter of the first year. This course, given under the direction of the physics department, is made an introductory course in science, so that the student is more or less familiar with the words and phrases that he will be required to use in his problems in algebra and geometry. [These experiments are published in full in an appendix to the report mentioned above.] . . . A pertinent question would be: What assistance has this been to physics? The student is familiar with many of the words like velocity, acceleration, force, centigrade, etc., the metric system in detail, and the graph. He can solve all algebraic equations occurring in physics with numerical examples under each. The working of examples in the composition and resolution of forces with the trigonometric functions—sine, cosine and tangent is but a continuation of his work in geometry. The laws of the lever, reflection and refraction of light, of the inclined plane, and the relation between the Centigrade and Fahrenheit thermometers come as easy as the simplest equation in algebra. From his laboratory work he is familiar with the method of doing accurate laboratory work. He knows the *degree* of accuracy which he may expect to obtain, i. e. a clear relation between the theory and practice. He is also familiar with the sources of error, the form of laboratory report, and he knows the best methods of computation . . . Another question which is often asked and which is certainly much to the point is: Do these students know the pure mathematics as well as students who have had only the abstract mathematics? This is, of course, a very difficult question to answer. I have made an attempt to find an answer in this way. I have in my classes not only students who have taken this work, but also students who have come to us from first class high schools where I know that the preparation in pure mathematics is very good. I have sometimes asked for the proof of some geometrical theorem that we have been using, as for instance the Pythagorean theorem. I have never yet found a student with only the abstract preparation who would attempt to demonstrate one of these offhand; while I have found that a large number of the students who have had the concrete geometry were able to give the demonstration. While this can not be considered in any sense a proof it certainly indicates to me that the student has lost none of his reasoning powers by taking up this applied work.

Professor Bishop in the same paper reports the progress in correlation made in some other collegiate institutions. Professor Woodworth of the department of physics in Lewis Institute says:

I take great pleasure in reporting progress in the correlation of mathematics and physics at Lewis Institute. I have been more than pleased with the results as they develop this year. The students who had the mathematical work based upon actual measurements are much better prepared than those who have had the same amount of abstract work in mathematics. The work seems in some way to have developed a thinking mathematical method which largely prevents those mathematical blunders which have been so exasperating to physics teachers. I also think the attempt at precision measurement has increased the students' reverence for mathematics.

Dean Raymond, professor of physics in Armour Institute, writes:

We have found at Armour Institute that in attempting to do specified physics experiments with our mathematical classes, we sacrificed the formal drill in the manipulation of algebraic expressions. This is too important a part of the training of an engineer to be studied in any but a rigid manner. In place of the "booky" problems that are found in almost every text, we have supplied a long list of problems from physics, especially mechanics, etc. [without abandoning the use of a text]. The law is stated and the student has problems to solve that arise from the law. The interest of the student is assured at the outset knowing that he will later meet with the principle in his engineering work. Besides the interest of the student, he is being drilled to manipulate those forms which will make the study of mechanics or physics very much easier when taken up.

Professor Greenwood of McKendree College writes:

We are trying to bring mathematics and physics into close relationship by showing that algebra is a means of expressing relations among magnitudes which may be measured and of expressing relations deduced from given relations. I am using entirely new definitions with these ends in view, and as far as I know they differ widely from the textbooks. We take any verbal statement from physics or arithmetic and then state it in the form of an equation. From equations we state verbal equivalents or rules. We leave entirely in the physical department the experiments from which the laws are deduced.

After quoting similar experiences from other institutions, Professor Bishop sums up his article by saying:

From the statements of various persons quoted in this paper, and from others which I have obtained, it seems that correlation does not mean that either algebra or geometry or physics is to be eliminated, but, as Dr Milliken very aptly expresses it, "you can teach all the physics you want in algebra and geometry and then there will be plenty left for us."

It appears that the correlation is an accomplished fact in so far that problems from physics are made the basis of the original work in algebra and that wherever this work is carried on we find both the mathematics and physics teachers enthusiastic concerning the progress of the student in his power not only to use his mathematics, but he seems to possess a clearer and a more correct idea of the abstract mathematics.

I hope these long quotations will seem to you justified by the highly instructive way in which they show the principles of correlation at work under various conditions. We see in the higher institutions the same varying degrees of correlation as in the secondary schools. Each institution seems to be feeling its way toward maximum efficiency under its own peculiar conditions. There does not seem to be any reason why the same principles may not be applied in the East in a similar spirit. There is ample material in the report of the committee mentioned above, with its appendixes, and in the various articles to which I have referred, to enable any school to make careful pedagogic experiments in its own way. The authorities are not so blinded by love for present methods that they can not recognize improvements when they see them. We can, at any rate, all practise a kind of correlation which is far more fruitful than any paper scheme. We can cultivate a high degree of sympathy and mutual understanding among all the teachers of all the grades of all the allied subjects; and we can then let the mutual action and reaction of all the subtle forces do their perfect work in leading up to that adjustment which produces maximum efficiency. There is already much of this spirit in our schools and colleges, and it is worthy of cultivation and development.

I may here say a few words about the practice at Cornell. At the conferences of the related departments, when the mathematicians ask the teachers of science or engineering what their students need most, they reply:

We want all the mathematics you can give them in the time at your disposal. We need, in the first place, facility in numerical computation. We want the student to have a well developed arithmetical sense, so that he can readily predict a rough approximation to the result of a numerical operation, and readily check the result when obtained, and so that he can also recognize what degree of accuracy is necessary and sufficient for the problem in hand, that he may not waste time in useless computation. Again we want the student to have facility in algebraic transformation, and in representing all kinds of functional relations graphically. He should have his analytic geometry and calculus so well in hand that he can see readily what interpretation to give to the characteristic features of the graph, e. g., the intercepts on the coordinate axes, the slope, the area, the direction of bending, the inflexions, the crests and troughs. He should be able to work as readily with the variables space, time, volume, pressure etc., as with the formal x and y. We don't like to have to turn aside from our own work to show them such things as these. We realize that we shall have to turn aside a little, to make good connections, but we want your assistance in reducing this to a minimum.

To attain this end, suitable problems are devised, not requiring much physical explanation, but involving the kinds of mathematical transformation and computation that will be of most immediate use in the allied departments. In return the mathematical teacher borrows illustrative material from the physical sciences, selected for its intellectual value and availability. The advanced work in mathematical physics is divided up among the professors of physics and mathematics, and is sufficiently coordinated. No part of the instruction in any department is merely utilitarian, least of all in the college of arts and sciences, where the note of idealism is dominant.

I would say, in closing, that since it is the high duty and privilege of every teacher to contribute an ideal element to whatever he touches, he should be allowed a generous freedom. There are diversities of gifts with the same spirit. The teacher of any of the related sciences has a golden opportunity to strengthen the faith of his pupil in a deep-lying correspondence between the world of nature and the world of the pure intellect, by showing him the progressive correlation that can be read on the pages of history; thus leading the pupil to a firm belief in the intellectual basis of the wonderful cosmos of which he is a part; so that standing on the solid earth, and counting nothing human alien to him, he may become a seer of far visions.

THE ALTERNATING CURRENT

BY JOHN F. WOODHULL, TEACHERS COLLEGE, COLUMBIA UNIVERSITY

1 Show by milvoltmeter and wire rectangle how alternating current is produced. Using four dry cells on the field coils—5.5 volts, 1 ampere.

2 Convert this into direct current by commutator.

3 Show that an alternating current is produced when the armature revolves in a field having only residual magnetism.

4 Ring a bell and light a lamp with the alternating current produced by a magneto. Lamp requiring 10 volts and .1 ampere.

5 Light a lamp and operate a telephone receiver by the alternating current which is produced in the magnet of an ordinary clatter bell when rung by a direct current.

6 Send 110 volt alternating current through 100 inches of no. 24 iron wire without other resistance, to show expansion by heat; to teach coefficient of expansion; to show resistance increased by heat from 1.5 ohms to 14 ohms. File a spot to show increased resistance and increased illumination with *apparent* increase in size. Fuses. Welding.

7 The study of electric measurements with the alternating current by means of incandescent lamps.

$$\text{16 candle power, .5 ampere} = \frac{\text{110 volts}}{\text{220 ohms}}$$

55 watts, 3.5 watts to 1 candle power.

$$\text{32 candle power, 1 ampere} = \frac{\text{110 volts}}{\text{110 amperes}}$$

110 watts, 3.5 watts to 1 candle power.

8 Show arc light run with 10 amperes of 110 volt alternating current.

9 Show telegraph sounder operated by one ampere of 110 volt alternating current.

10 Show clatter bell operated by half an ampere of 110 volt alternating current; connected as a single stroke bell but operating as a clatter bell. Ring magneto bell with 110 volt alternating current.

11 Show a homemade motor run by one ampere of 110 volt alternating current.

12 Run electric fan and electric car by alternating current.

13 Operate Ruhmkorff's coil by alternating current on the primary.

Transforming the voltage of the alternating current

14 Light two 20 volt lamps each requiring one ampere by sending 1 ampere of 110 volt alternating current through ring transformer. 110 watts reduced to 40 watts, and 32 candle power reduced to 12 candle power.

15 Light one 240 volt lamp requiring one quarter of an ampere by sending 1 ampere of 110 volt alternating current through ring transformer. 110 watts reduced to 60 watts, and 32 candle power to 16 candle power.

16 Light a 10 volt .1 ampere lamp by sending 110 volt alternating current through transformer.

17 Light a 3 volt .5 ampere lamp by transforming 110 volt A. C.

18 Run toy motor by reducing voltage of 110 volt A. C.

19 Operate ordinary bell by reducing voltage of 110 volt A. C.

20 Operate telephone receiver on the secondary coil with 110 volt A. C. on the primary coil.

21 Operate magneto bell on the secondary coil with 110 volt A. C. on the primary coil.

22 Illustrate stepping up the alternating current for long distance transmission and stepping it down again for use.

Transforming the alternating current into direct current

23 Describe the Churcher chemical rectifier. Some results obtained from it are shown in the following table:

UPPER COIL

Ohms	Volts	Amperes	Watts
∞	15	0	0
100	10	.1	1
19	7.5	.4	3
14	7	.5	3.5
6	6	1	6
2.5	5	2	10
1.6	5	3	15
1	4	4	16
.7	3.5	5	17.5
.6	3.5	6	21
.4	3	7	21
.2	2	10	21

LOWER COIL

Ohms	Volts	Amperes	Watts
∞	67	0	0
600	60	.1	6
215	43	.2	8.6
80	40	.5	20
30	35	1.2	42
15	31	2	62
9	26	3	78
6	24	4	96
4.2	21	5	105
3.6	20	6	120
2.6	18	7	126
2	16	8	128

Ohms	Volts	Amperes	Watts
1.7	15	9	135
1.3	13	10	130
.9	10	11	110
.7	8	12	96
.5	7	13	91
.3	5	14	70
.2	3	15	45

In the following 8 experiments, 110 volt alternating current is sent into the rectifier and a direct current is produced as specified in each case.

24 Light direct from lower coil a lamp whose characteristics are: 50 volts, 100 ohms, .5 ampere, 25 watts, 7 candle power.

25 Light a group of 5 lamps in parallel from lower coil: 20 volts, 4 ohms, 5 amperes, 100 watts, 30 candle power.

26 Light from upper coil miniature lamp. 10 volts, 100 ohms, .1 ampere, 1 watt, .25 candle power.

27 Light from upper coil by adding 7 ohms miniature lamp. 3.5 volts, 7 ohms, .5 ampere, 1.75 watts, .5 candle power.

28 Run small motor 1 volt, 1 ohm, .1 ampere, 1 watt, by adding 5 ohms and connecting to upper coil.

29 Bell: 1 volt, 6 ohms, .25 ampere, .25 watt.
Add 6 ohms in shunt with bell and control by 11 ohms in series with bell. Connect with upper coil.

30 Deposit copper from copper sulphate solution by connecting with upper coil. 5 volts, 2 amperes.

31 Using this copper sulphate cell as a storage battery, show that it will ring a bell.

32 Describe the Evans A. C. motor—D. C. dynamo. Some results obtained from it are shown in the following table:

Ohms	Volts	Amperes	Watts
∞	22	0	0
21	21	1	21
10	20	2	40
7	20	3	60
5	19	4	76
4	19	5	95
3	18	6	108
2.5	18	7	126
2	18	8	144
1.5	15	10	150
.3	5	15	75
.1	2	18	36

33 Light a group of 5 lamps
20 volt, 4 ohms, 5 amperes, 100 watts.
This machine will run on 110 volts D. C. and furnish 20 volts either D. C. or A. C.: will run on 12 volts D. C. furnishing 20 volts D. C. or A. C.; and
Will run on 110 volt A. C., furnishing 20 volt D. C. or A. C. with such variations as are shown in the table above.

34 Show how to get *any voltage*, from 1 to 20, on *very small current*, for ringing bells, electroplating, etc.

Section B—BIOLOGY

SETTLED AND UNSETTLED PROBLEMS IN HIGH SCHOOL BIOLOGY

BY WAYLAND M. CHESTER, COLGATE UNIVERSITY, HAMILTON

What may the teacher consider as settled among the questions that appear when he attempts to plan his course? What, judging from our educational literature and the practice of our best teachers, may be beyond discussion, or in the local conditions of the State, be taken for the present as agreed upon? Among the questions still unsettled, what are the present most vital problems? In such unsettled problems, do we differ in principles, or are there principles upon which we agree, but whose influence in individual courses may be so different that discussion and experiment must still be used to prove the procedure wise or unwise?

The teacher's problems depend upon the aim of his teaching, and in such aim for biology, to a large extent, there is agreement among educators. The agreement would consist in this, that the teacher's aim should be to inculcate strength and culture, by discipline in the habit or spirit of the scientific method, through information that has been classified as esthetic, moral, practical, and intellectual.

Recall the well known steps of the scientific method of thought in order to make it clear at the start just what it is we think our student should gain in discipline. It involves (1) observation, or observation with experiment or analysis, (2) generalization from such observation, (3) deduction or hypothesis from the generalization, and (4) experiment or observation to prove such deduction true or false. Our science should contribute with the other sciences toward the training of these mental processes involved in observing, analyzing, comparing, judging, constructing, and proving until the student shall have in the final total, as nearly as possible, the habitual attitude of seeing and expressing accurately and clearly the steps in the process of thought and the sequence of the steps;

and shall have an independent initiative in each step and a conscious accuracy of result. The teacher aims in the time he has the student to do a part toward molding a mind, accurate in seeing and open to truth, an attitude expressed by a late writer as "a ready exposure of the mind to new evidence," a mind alert, patient, independent, and self-directing. This aim means the training of mental processes which develop in the child and are always active in the man and which the man trained and untrained will follow; but which in the trained mind may lead away from uncertainty, but without discipline toward inaccuracy, the following of wrong guides, or toward prejudice, folly, or superstition.

As to just how far or how much we should contribute toward this result, I think the rank and file of our teachers would not agree in practice. There is a general feeling, representing some truth, that our science is preeminently valuable for training in the processes of observation or classification and that other sciences are emphatically valuable for other processes; and occasionally a ringing voice in the field of either science will give expression to just that. It must be further seen that if we succeed in contributing in making the pupil an accurate observer and an observer open-minded and demanding accuracy; or if we can train the mental processes involved in distinguishing the essential from the unessential and in generalization, we are accomplishing what will be of untold value to the man. At the same time our science, and probably the other sciences as well, have the possibilities of aiding in training in the other steps of the method and the sequence of them; and the teacher does not have the highest ideal of the possibilities of his science as an instrument until he sees and appreciates this fact. Shall I try to any extent to discipline all the processes involved in the scientific method, in the sequence of them, becomes a first large question for the teacher, which will surely make a difference in his planning. Nearly every recent writer who is a biologist has emphasized the need of giving the student some problems that shall involve more than observation or classification if not the whole method. Coulter for botany says recently "Beyond analysis lies synthesis, and this certainly represents the ultimate purpose of science. The results of analysis are as barren as a bank of sand until synthesis lays hold of them. It is just here that a large amount of science teaching fails, for to many teachers the accumulation of unrelated facts seems to be the end of scientific study, and the results of the laboratory may be represented by a chaotic pile of brick rather than some definite structure dominated by an idea. Almost any one may accumulate facts, but to relate them, to distinguish the significant and the insignificant, to recognize that they are merely external expressions of something general belongs to the highest stretches of scientific training." [J. M. Coulter. *School Review*, Oct. 1904] And Bigelow writes "In order to make the study of zoology most valuable as discipline in the scientific method, the essential processes and their relations must be kept constantly in mind by the teacher who directs the practical studies; and it should be the constant aim of the teacher to lead the pupils to apply as far as possible the principles of the scientific method in discovering truth for themselves."[M. A. Bigelow in *The Teaching of Biology*] The teacher's aim should be then to train the processes of mind in the scientific method of thought, in not one step of the process alone but to a certain extent in the whole sequence of them, through information that is esthetic, moral, practical, and intellectual in its value; and in the attempt to gain this result some problems are for the time being settled and some unsettled.

1 The problem of minimum time, which is (1) a problem of time necessary to give good values in the subject and (2) a question of correlation between the sciences of biology and between biology and other sciences is for the time being settled. One year is thought to be necessary for good results in any science. Following the change in thought that gave a disciplinary value to the subjects and the advent in the high school of laboratory work, this minimum time of one year was first required by the colleges for entrance, in which botany and zoology could take the half year, though it was advised that one or the other be given the full year's time. There has been a growing wish to place the study of human physiology, often an information study, on a disciplinary basis and to look at it from the biologic standpoint. There has further been, I think, a growing wish and practice to present zoology and botany consecutively. At present in this State we advise a year's work of botany and zoology with human physiology and are thereby covering more ground in the year's work than we have before expected. I do not however feel that we have retrograded since the biology of man belongs with zoology and since human physiology must of necessity be somewhat better taught in a great many schools. A doubt that the year is not long enough however may be the reason for the expression of the opinion that an extra course in a later year be given where it is expedient; though it is

doubtful if we can ask more than one year in correlation with other sciences.

2 The place in the course, while not generally agreed upon in other states is for the time being settled for us in this State as the first year. But we must remember that our experiment in botany, zoology and human physiology in the year is matched by a half year or a year of either science in our own and other states, and of science in other years than the first; and the result may later offer interesting comparisons.

3 It is settled that laboratory work shall contribute a large share of the work of the course. The use of such work in biology in the high school is comparatively recent, but in the 10 years that it has fairly been in existence with us, it has become well nigh universal, and is a point insisted upon by every good teacher. Of course there are still found some schools where textbook courses exist as there are schools where biology is taught as an adjunct, but with us the courses now outlined will certainly increase the use of laboratory method. By the large use of the laboratory we mean the aid in gaining the scientific spirit with the gain of biologic knowledge by the large use of personal, accurate observation, personal judgment and deduction in a room equipped to aid such personal work, and in the field where with less comfort but with the natural complex environment, the student may still personally gain his knowledge. The laboratory is an instrument, like the appliances used there for making knowledge real, whose successful use depends on its manipulation by the teacher.

4 In the problems related to the contents of the course this much is agreed upon—that the great subdivisions, morphology, classification, physiology, and ecology shall be represented. This is nearly the same as saying that the demand is met that the teaching shall be dominated by the conception of the animal and plant as alive and doing work; of physiology interpreting anatomy and morphology, of structure largely explaining the method by which work is done, and of classification as the expression of much of our knowledge of forms.

Now a tendency should be noticed. In our science at least, the individual teacher is left free to plan the details of his course and guide his student, and his individuality and force are trusted to execute in the way to gain good and sure training. Variability in the material, in the laboratory equipment, the field possibilities, and even for the present in the teacher himself, is recognized. It is true that our high school teaching of biology is in its youth, and that our ideals in presentation may become more uniform later. It is true that we need more studies as object lessons in the presentation of individual topics to insure discipline in the whole method of thought, that expert judgment will be needed in settling many things in the unsettled problems; but it is also true that the settling of details centers in the individual teacher and according as he appreciates a high or low aim for his instrument, as he knows and guides his pupil and as he handles the content of his course, will his results be of high or low grade.

5 One important unsettled problem is the relative proportion of the subsciences of morphology, classification, physiology, and ecology, and the proportioning of the groups of animals and plants in a one year course. The teacher finds at hand definite expert opinion of relative amounts in a whole course in certain standards. Among these are, the Regents specifications for a first year's work, the College Entrance Board's requirement for botany, approved by the Regents for a later course, and a college entrance option in zoology adopted by the American Society of Zoologists and approved as a later New York State course. There are also other statements as in Lloyd and Bigelow's *Methods*, those that have been presented before this section, and the college entrance option of Harvard. Most of the recent text and guide books influence in proportioning, though usually leave the matter with the teacher. There are further recent statements of ideal by Needham [J. G. Needham. *Science*, 19:650] and Hodge [C. F. Hodge. *Pedagogical Seminary*, Sep. 1904]. These standards, if we may find likenesses among so many diverse characteristics, divide themselves roughly into three groups, according as a few types for completer study in emphasizing structure and physiology are used; or as all phases of each subscience are given proportionate treatment; or as the standard is confessedly a natural history or ecology course. Of the second group, some of which will partly guide us in this State, the outlines for a complete year's work in botany alone or zoology alone are notably alike in the principal topics to be taught. These are, elementary classification and exercises in classifying as part of the generalization work; detailed structure including dissection of a limited number of forms (nearly one from each type); the physiology of these in animals and of the organs of the seed plant; the reproduction and life history of the forms studied; the ecology of forms from the larger groups of animals and of the organs of the seed plant; but when botany and zoology cut the year into two parts the problem is less near a solution if

we expect uniformity. In zoology the reduction most notably occurs in one point, in the study of the structure and physiology of an invertebrate and a vertebrate, and the courses are more nearly uniform, but on the botany side there is choice in the general principles, worked out most often with the seed plants alone; in the natural history of the groups; and in a course including both, which the advocates of the others would feel was not educationally superior or equal.

The last group shows an outline for the high school as simply natural history and represents the extreme tendency toward the use of the animal as alive and the use of practical information. Quite recently a paper by Hodge (C. F. Hodge. *Pedagogical Seminary*, Sep. 1907) has emphasized this tendency in a very suggestive way. "The high school, as part of the public school system, should have its courses coordinated with those of the grades. High school biology, under this view, would form the normal completion of elementary nature study and should aim to fit the great majority who do not study farther for intelligent citizenship in harmony with the forces of living nature. I can hope only to open the discussion of this important question but from all I have been able to gather on the subject in the past five years, I am constrained to conclude that the line between practical nature study and technical biology should be drawn between high school and college rather than between the high school and the grades. And I take this position for two distinct reasons. The first is that pupils of high school age are not mature enough and lack the power of thought and the mental perspective to sense the signifi- [illegible] The other reason is that there [illegible] knowledge, now neglected, which it [illegible] more valuable to the a[illegible] [illegible] body of knowledge [illegible] such body of [illegible] knowledge of t[illegible] in the life of man. And such drill in research he finds practical in high schools that have come under his observation. "Every living organism represents a certain force, does a certain amount of work. Determine this with the greatest care for the individual and multiply by the number of individuals of the species and we gain an expression for the power of a species as a whole. We learn the species not merely as a dead form, but as a force in nature. And further, study all species of animals from this point of view —or for practical courses select dynamic types—and we develop a picture of nature as a vast stream of living forces acting and reacting upon one another, a picture of nature as it lives, moves, and has its being; and we gain a view of the dynamic process of organic evolution." This article will prove inspiring and suggestive to every teacher though some will differ, thinking that, while the dynamic standpoint and the practical information are very important, we should yet teach our science as a science and aim to give as wide a knowledge of the subject as the mind of the child and the time of the course will permit. It is true that the detailed course suggested in one article for the first year of the college, although with the point of view of forms as dynamic forces doing something to the outside world and for themselves is a most logical, consistent, and balanced whole from the standpoint of the science, that except in detailed methods will appeal to many instructors; but he would seem to limit his high school course to one dominated by the fact of forms working on external nature and if this is true make it partial rather than synoptic in its scope and to do it mainly because the pupil lacks the power of thought and mental perspective.

There are certain principles some or all of which have been kept in mind in shaping standards or ideals. They are however often opposed to each other. (1) The course should give the dynamic point of view of forms as alive, which may mean one or all of these three phases—the form doing work for itself in its specific way, exerting force on the ou[illegible] world, or helping or hindering the
work of [illegible] should be given a broad view of
th[illegible] a knowledge of organisms
[illegible] the time makes possible.
[illegible] principles demand other-
[illegible] forms as higher or lower;
[illegible] of for study as the seed
[illegible] ther; that these and each
[illegible], ecology, and classification

must be investigated for their possibilities in training and information values. This principle alone means a course thoroughly synoptic. (3) The course should be one adapted in its content to the needs of the child who goes from the high school to his life in the community. "It must relate the pupil to his most common experiences," "It must be in the long run orderly and progressive development towards fitness for the activities of life" are late expressions of this principle. (4) The course should show the characteristics of definiteness and thoroughness for training in the method of thought.

For discipline in the method of thought, through knowledge of forms as alive, in a synoptic course, and definite and thorough in its attempt, each composite standard of the second group is an expert attempt to combine the fundamental principles of physiology and ecology in actual laboratory and field work, with their great value in experiment and reasoning, in giving practical knowledge, and widening the intellectual view; of morphology as a basis for the study of the other divisions, as excellent for cultivating exact, discriminating, and concentrated observation, with minute and internal anatomy enough to understand the principles of physiology and structure building; of life history with its innate interest, its industrial value, and its aid for all steps of scientific reasoning; of the essential facts of reproduction, heredity, and variation; and of classification as needed to express and arrange the knowledge of structure gained and as student aid in the ability to generalize. The nature study and natural history group have as well had in mind the discipline, with live forms, in a thorough course adapted to everyday life; and the outlines are in some cases synoptic though in others not, but in all reduce the study of one or more groups or subsciences toward a minimum. To gain a knowledge of the different groups of animals and plants a synoptic course that is also synoptic in the divisions of the science is hard to plan in the limited time. The elimination of groups is often made because definiteness and thoroughness seem to demand a stopping point somewhere. Our first group courses are synoptic in the use of types because thoroughness is thought to be hindered by the use of many forms, though narrowness of impression may be incurred, while those of the second group are synoptic with reference to the subsciences.

6 The order of material in a course will be found (1) from simple, one celled forms to the more complex, (2) from the better known, complex forms to the simple, (3) with either order preceded

by a study of a known form as a crayfish, fern, a seed, or fruit. In either of these orders, morphology, physiology, ecology, and classification have been studied separately; or have been taken synthetically with the forms studied or with the seed, root, leaf, and flower; and in the synthesis morphology or physiology have been in different instances the starting point. All the orders seem to have been successful with different teachers.

7 The relative amount of verification and investigation, and of laboratory and textbook work offer more serious problems to the teacher. By the use of information the student is to gain in the end the habit of independent, self-reliant, accurate observation, and the ability to do something in reasoning. Remembering that the learning of these will require much drill, can we initiate the reasoning process best by leading the pupil to see what you tell him is there, or by guiding or stimulating let him find for himself? It is true that a maximum of the verification method is used by some successful teachers, and as true that many more have found by experience that better results are gotten under strict guidance by the boy searching for himself and the teacher watching, not to tell for information's sake but by questioning or by a fact perhaps leading the process of right reasoning. The question is how much shall be told and how much found to gain the greatest power to do in the shortest time? And the answer to it is that the teacher shall watch the student's activity rather than his command of knowledge, and guide by a question or a statement that shall lead to interest and to independent further steps in the process of reasoning. It is here, in the formulating questions for the period and in watching and guiding his student that the teacher's individuality and originality is most important. In ecology particularly is found a great need for definite guides in gaining the spirit of the method of thought.

The relative amount of laboratory and textbook work is a problem of the same character, to give the greatest amount of successful training with practical and intellectual knowledge in the shortest time. We must here emphasize the need of using the information and the generalizations of authors not always for their knowledge value alone, but as a broader basis for student generalization and as an aid in making and proving hypotheses. We rarely appreciate the possibilities of literature in this respect, or successfully adapt it toward the gaining of power. Here again the teacher is the chief factor. This suggestion has greater need of emphasis when we remember that the tendency to gain knowledge from a text is a hardly resisted impulse in our pupils, and especially in the problems of ecology teachers themselves are easily drawn to use alone, in teaching, well written books.

8 The economic correlation of botany and zoology offers, in the possibility of arrangement other than that of consecutive wholes, I think, a problem that will not yet appeal to most teachers since the question has scarcely been raised. Most teachers seem strongly of the opinion that botany and zoology should be kept as separate wholes since the intermixing of plants and animals may lead to confusion and the two lines of development are divergent. There are also practical reasons in some places where students begin biology either in the fall or in midwinter. But the fact that the same principles may be found in both plant and animal phenomena, together with the fact that plants and animals do not lend themselves equally to laboratory investigation of them, leads me to think that there is a present problem in their close correlation that needs much discussion and experiment. Animals do not easily adjust themselves to the study of the fundamental facts of digestion, respiration, and excretion, and plants such as seedlings do, while animals are equally valuable for the study of irritability. The external facts of reproduction are illustrated in an excellent way in plants. Plants and animals can be correlated in the study of food-getting and the importance of photosynthesis to both groups emphasized. Organisms are built of similar units. They work together, helping or hindering. Both groups of them are living things, showing the same fundamental phenomena, and we are beginning to feel they should be studied together; but we keep them separate when we think of divergent development, although development is also divergent within the groups, but we ought to study them together when we think of the fundamental ideas and phenomena they exhibit.

Section C—EARTH SCIENCE

OPENING OF DISCUSSION ON SYLLABUS IN PHYSICAL GEOGRAPHY

BY CHARLES NEWELL COBB, STATE EDUCATION DEPARTMENT

It seemed necessary in the preparation of a syllabus in physical geography to bear in mind the following aims:

1 That a year course be substituted for the former 20 week course.

2 That as astronomy and geology are dropped from the Academic Syllabus such parts of these subjects as are more closely related to physical geography and are thought more suitable for students in secondary schools be included.

3 That the course be made suitable for second year students who wish to meet the requirements of the College Entrance Board and that it be capable of expansion to satisfy the larger demands of more mature students in the fourth year.

4 That laboratory and field work be made an integral part of the course.

As greater combined experience in teaching a year course in the subject was found in New York city than elsewhere and as the New York city teachers of the subject had a good working organization to improve this teaching it seemed wise to secure ideas and material from this source. Their assistance was accordingly early enlisted.

Personal consultations were also secured with those in charge of the work in this subject at Teachers College, Colgate University, Cornell University and Oswego State Normal School, gentlemen who have been active in this association. Dr Clarke of the State Museum also gave valuable aid.

As the result of these efforts most valuable material, suggestions and criticisms were secured.

It was thought better to group the laboratory exercises as they have not been so thoroughly tested by experience and are considered not so well digested as the rest of the syllabus.

Much suggested material is omitted and some not suggested is included. The order of arrangement is not necessarily the best but it is thought to be good. Kindly criticisms have been made by those well prepared to criticize and counter criticisms have come from equally high authority. The writer of a letter recently received believes that too much matter is included, mentions a single item that he thinks might be dropped and wishes a half dozen added.

Finally that which is of value in the syllabus may be largely credited to those who have so unselfishly cooperated in its production, while if anything is omitted that shou'd be included, or included that should be omitted, or if the arrangement is not so good as it should be, the fault may be charged against the speaker.

NEBULAR AND PLANETESIMAL HYPOTHESES TO ACCOUNT FOR THE ORIGIN OF THE EARTH

BY T. C. HOPKINS, SYRACUSE UNIVERSITY

The *nebular hypothesis* as formulated by Laplace assumes that at one time the material of the sun, planets, and all the other members of the solar system existed in the form of a highly heated, attenuated gas, filling all the space now occupied by the solar system from the center of the present sun out to and beyond the orbit of Neptune.

Acting under the force of gravity this material began to contract and rotate as it cooled. The rotation would cause a flattening at the poles and a bulging at the equator until, it is assumed, the centrifugal force would cause the separation of a ring of nebulous matter at the equator similar in form to the ring surrounding Saturn at the present time. It is assumed that the ring would finally break up and collect into a globular mass rotating on its axis and, at the same time, revolving around the central mass.

It is held that the smaller mass would in the course of time throw off one or more rings similar to the first, which in turn would break up and form smaller bodies revolving about the larger mass and corresponding to the satellites; the larger mass first thrown off forming the outer planet Neptune.

As the main central mass continued to contract, it is held that it would throw off other rings which would form the other planets and their satellites in the same way; Mercury being the last to form, and the sun being the remnant of the original mass which is still in process of contraction and cooling.

The nebular hypothesis, with some modifications of the preceding outline, has been stated and advocated by Kant, Herschel, and others, at different times, and in some of its varied forms has been pretty generally accepted as the best explanation that has been offered for the origin of the earth and the other members of the solar system. There have been objections raised to this explanation, but it seems to explain so many things and is such a bold conception that it has held a prominent place in scientific literature since its first inception.

Some of the prominent physical and astronomical objections to this hypothesis are:

1 The great inclination of some of the orbits in the system. One of the strong arguments in favor of the hypothesis is that all the bodies revolve and rotate in or near the same plane. Yet Neptune's satellite has its orbit inclined 35 degrees and those of Uranus have either backward motions or the anomalous inclination of 97 degrees.

2 There is a decided lack of uniformity and system in the distribution of the masses, densities, and moments of momentum that would seemingly be required. Jupiter alone, it is stated, took 95% of the moment of momentum of the nebular mass at the time of its formation.

3 There is a wide variation in the rates of revolution that is not satisfactorily accounted for. The inner satellite of Mars

revolves three times as fast as the planet rotates, while our satellite, the moon, revolves only $\frac{1}{29}$ as fast as its planet.

4 The high molecular velocities of the lighter gases would apparently cause them to escape from the rings postulated by the theory.

5 The rarity of the original nebula would be $\frac{1}{240000000}$ of that of average air, and it would seem that there should be a continuous throwing off of gas particles instead of the separation of a ring of matter.

6 Even if a ring were formed, some mathematicians claim that it would not collect directly into a globular mass.

7 The hypothesis is not in accord with the requirements of the law of constancy of moment of momentum which is a fundamental principle in the hypothesis itself; nor are the ratios of mass and momentum consistent.

8 The ninth satellite of Saturn, recently discovered, revolves backwards while the eight inner ones revolve forward.

Objections 7 and 8 are very grave, if not altogether fatal.

Beside these physical objections there are a number of geologic objections, some of which are:

9 The continental land masses and the deep ocean basins are not satisfactorily accounted for on this hypothesis.

10 The continued uniformity of the atmosphere is difficult to explain.

11 The high development of life in the earliest fossiliferous rocks indicates a very long period of time preceding their formation in which conditions for life must have been possible, a longer period of time than the hypothesis apparently warrants.

The aggregate of the difficulties involved in this hypothesis, which have been tacitly overlooked, instead of satisfactorily explained, led Professor Chamberlin first to try to develop the meteoritic hypothesis into a satisfactory working form and, failing in this, to develop the *planetesimal hypothesis*, which departs radically from all gaseous and meteoritic hypotheses.

The *planetesimal hypothesis* assumes that the solar system was derived from a spiral nebula which is supposed to have been formed by explosive protuberances from an ancestral sun under the influence of another sun or large body passing near it. The knots of the spiral nebula are assumed to have constituted the nuclei of the planets and satellites, while the more dispersed matter (which was gaseous when shot forth from the ancestral sun and later cooled to minute bodies) was in time gathered to the nuclei to form the planets. These dispersed particles, together with the nuclei, are assumed to have revolved around the sun in elliptic orbits, like the planets, from the time of the formation of the spiral nebula onwards, and hence they are called planetesimals. The dynamic organization is thus supposed to have been radically different from that of the gaseous or meteoritic nebulae postulated as the origin of the solar system under the two preceding hypotheses.

The growth of the earth under the planetesimal hypothesis consisted in the gathering in of the planetesimals very slowly by the conjunction of their orbits with that of the earth nucleus. While much heat would be generated by the collision of the planetesimals with the earth nucleus, it is assumed that this would be largely lost by radiation during the slow process of accretion, and hence that the earth was probably solid at all stages of growth. The internal heat of the earth is referred chiefly to compression under gravity as it grew, and subordinately to the heat of impact, molecular combination, radioactive processes, etc. Under this hypothesis much gaseous material is assumed to have been carried into the body of the earth and occluded in the planetesimals. This has been coming forth by volcanic and other action ever since and feeding the atmosphere, and thus maintaining an approximate uniformity, for, if at any time the supply exceeded the usual rate of consumption, this rate would be accelerated, and the loss of atmospheric molecules to external space would probably also be accelerated.

Under this hypothesis the continental platforms and oceanic basins find an easy and natural explanation. Under it also it was possible for life to have been introduced long before the growth ceased and thus the high state of development of life at the time Cambrian sedimentation began is explained. Many other geologic difficulties find ready explanation under this hypothesis.

Unless further investigation shall show some radical defect in the planetesimal hypothesis, it is likely to prove more acceptable to the working geologist than the older hypotheses.

Section D—MATHEMATICS

Joint session with section A

SECTION MEETINGS

Thursday morning, December 28

Section A—PHYSICS AND CHEMISTRY

THE TEACHING OF CHEMISTRY IN THE SECONDARY SCHOOLS: A STUDY OF RECENT PRACTICE AND RESULTS

BY WILLIAM C. GEER, CORNELL UNIVERSITY

1 Introduction

During the past few years there have appeared in the educational periodicals a number of articles on the course in chemistry which should be given in the secondary schools. In 1900 a committee of the New York State Science Teachers Association obtained the opinions of many teachers in the State, outlined a course and suggested methods of teaching. These proposed courses set, let us say, the standards. It is interesting now to observe, in a comparative manner, the prevailing practice and determine the results.

In the fall of 1904 it was my pleasure to read the chemistry notebooks which were presented for entrance to Cornell University as part of the necessary credentials, by those who entered without examination. Accompanying each notebook was a card upon which was written certain facts about the course which the student had pursued. These facts were necessary in order to know of the nature and extent of that course.

During the study of these books and data it became evident that this was the best possible way, short of an actual visitation, to learn the methods and results of secondary school work. Here were the credentials which the teachers and students were willing to have reviewed as evidence of the quality and quantity of their work. Yet it was not specially done, as for an exposition, but represented the honest, faithful, daily work of both student and teacher under ordinary conditions.

The data gathered in 1904 were amplified by those from the credentials of 1905, the whole classified and rearranged and this paper written after the two years' investigation.

No attempt was made to arrange the subject-matter presented in the different schools, for that offered no especially interesting features which were not more or less common to all the courses. The time spent on the laboratory work, the character of the record of the experiments, the habits of thought of the students and the quantitative experiments showed such remarkable diversity that these topics were made the important considerations in the classification.

Therefore, this paper will include, first, a study of the time spent in laboratory work, recitations and lectures; second, the different methods of recording the results of the experiments; third, the literary character of the record; fourth, the scientific character of the record; fifth, the results of certain special features of the course, viz, the quantitative experiments; sixth, some suggestions and observations as a natural outcome of the study. Photographs of pages of notebooks will be used as illustrations, although in no case will the name of any school be divulged.

The schools, from which notebooks were received, may be classified as follows:

a SCHOOLS IN NEW YORK STATE		
Public schools	83	
Private schools	23	
Total		106
b SCHOOLS OUTSIDE NEW YORK STATE		
Public schools	76	
Private schools	31	
Total		107
Total		213

The total number of notebooks read was 485.

2 Time spent on chemistry

Perhaps the best starting point in this discussion is a consideration of the amount of time spent in the study of chemistry. In general, three standards may influence the teachers of New York State. First, the report of the Committee of Nine,[1] in which it is stated that the laboratory work should comprise at least 108 hours all told, divided into periods of 1½ hours each and two periods per week; the recitations should occupy two 45 minute periods per week; and the instructor should give one experimental lecture per week.

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[1] University of the State of New York, High School Bulletin 7. 1900. p.714.

The second standard is that of the New York State Education Department. In the Syllabus of 1900[1], which prevailed at the time the notebooks here reviewed were written, there is given no definition of the number of hours to be spent in recitation or laboratory. Therefore, the work was done under no time limitation. For the sake of comparison with the other standards, it may be mentioned in this connection that in the Syllabus of 1905[2] the Department expects of its teachers "laboratory work consisting of exercises requiring 30 double periods of work." This reduces to 45 hours all told divided into periods of 1½ hours each and one such period per week. Classroom work and experimental lectures are required, although no number is mentioned.

The third standard is that of the College Entrance Examination Board.[3] This board is general in its statements but places the lower limit of laboratory work at 40 exercises. There is no numerical definition of the word "exercise." From a study of the 60 exercises listed it is evident that at least 1½ hours are necessary for each. The minimum requirement of the board may then be assumed to comprise 65 hours all told divided into periods of 1½ hours each and a few more than one per week.

There can be no doubt that other standards exist, for each college interprets these requirements according to its own ideas. Several of the colleges and universities demand of their entering students a preparation entirely independent of the standards named. Perhaps the difference of opinion on the part of the leading educators may serve to explain the wide variance in their practice. That such variance exists is one of the obvious inferences from this study.

Table 1 shows in what per cent of the schools the work was done in the more common divisions of time. The data are arranged by public and private schools as the natural and most interesting classification, and since, in New York State the private schools would probably show the influence of the College Entrance Examination Board, while the public schools would be more apt to show the influence of the State Education Department, or the Committee of Nine of the State Science Teachers Association. From the tendency of the public schools toward the shorter hours and the private schools toward the longer it would seem that these boards have had their influence, although this influence has not been of exceptional strength.

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[1] University of the State of New York, High School Bulletin 8. 1900. p.117.
[2] New York State Education Department, Secondary Education Bulletin 27 1905. p.82.
[3] Document 20. 1900. p.29.

Table 1

Time spent in laboratory work

HOURS IN EACH LABORATORY EXERCISE	PERCENTAGE OF SCHOOLS					
	SCHOOLS IN NEW YORK STATE			SCHOOLS OUTSIDE NEW YORK STATE		
	Public	Private	Total	Public	Private	Total
¾	36.7	18.2	32.7	31.6	6.9	24.8
1	22.8	27.3	23.8	16.8	17.2	16.2
1½	30.4	22.7	28.7	26.3	37.9	29.5
2	8.8	31.8	13.8	23.7	34.5	26.7
3	1.3	0.0	1.0	2.6	3.5	2.8
LABORATORY EXERCISES PER WEEK						
1	14.1	18.2	15.0	13.2	20.6	15.2
2	37.2	36.4	37.0	32.9	27.6	31.4
3	23.0	31.8	25.0	32.9	27.6	31.4
4	12.8	9.1	12.0	11.8	6.9	10.5
5	10.2	4.5	9.0	9.2	17.3	11.5
6	2.7	0.0	2.0	0.0	0.0	0.0
TOTAL HOURS						
0–50	8.9	9.1	8.9	2.6	10.3	4.8
51–80	24.0	22.8	23.8	21.1	10.3	18.1
81–100	21.5	4.5	17.8	22.4	10.3	19.0
101–120	19.0	36.4	22.8	22.4	10.3	19.0
121–150	6.3	13.6	7.9	14.5	27.6	18.1
151–300	20.3	13.6	18.8	17.0	31.2	21.0

In spite of the emphasis which, during the past five years, has been laid upon a laboratory period of 1½ hours in length, 36.7 per cent of the public schools of New York State still conduct their laboratory work in 45 minute periods, while only 30.4 per cent use the double period. In the public schools outside the State the situation is practically the same.

Less than the double period (1½ hours) is used in New York State by 59.5 per cent of the public schools, 45.5 per cent of the private schools and 56.5 per cent of all the schools in the State. In the schools outside of New York State the figures are still large, for of the public schools 47.4, of the private schools 24.1 and of all the schools 41 per cent use less than the double period

Nevertheless, excepting simple test tube experiments, the period of 1½ hours is none too long for a student to set up the apparatus for such experiments as the quantitative experiments, preparation of the acids, etc., perform the work thoughtfully, even the roughest of notes and take down and put away the apparatus. The majority of exercises outlined by the above mentioned boards can not satisfactorily be performed in less than that time. Perhaps some will say that they are using the short period with favorable results. Evidently many are gaining results, for the number of schools, in which this period is used, is large. But the boys and girls are driven at such an intense pace that their thinking ability is but slightly developed. The work in chemical laboratories is conducive to habits of quiet study. Things do not go rapidly. Attempts to rush are usually followed by disastrous results. One does not observe offhand why oxygen is evolved from potassium chlorate. A little thoughtfulness, at least, is necessary. But when excessive speed is demanded it becomes easy to form the habit of superficial thinking, which is one of the most common and most reprehensible habits formed by the student of chemistry. It is so easy for him to regard his chemical work as the mere mixing of so much "stuff" with a consequent play of colors, or an explosion.

It is noticeable that the shorter periods pertain among the public schools of New York State more than among any of the other classes named.

The double period is found in New York State in 30.4 per cent of the public schools, 22.7 per cent of the private schools and 28.7 per cent all told. Outside New York State the figures are not much different except with the private schools among which this period is employed by 37.9 per cent.

The longer periods are found more frequently among the private schools than the public schools, 31.8 and 34.7 per cent, respectively, finding place for the two hour period.

In the second part of table 1 it is seen that the majority of schools favor either two or three laboratory periods per week. In some schools there is only one period and in a very few as many as five or six periods. Two periods per week would seem to be sufficient to give all desired results.

There is even greater diversity in the total number of hours spent in the laboratory. If 100 hours be taken as the dividing line, then in New York State 52.4 per cent of the public schools spend less than that number of hours on the laboratory work. Outside New York State 46.1 per cent spend less than 100 hours in the laboratory. Among the private schools the figures are 36.4 and 30.9 per cent respectively. More time is spent on the work, therefore, outside of, than in New York State. Judged according to the standard of the Committee of Nine (108 hours), the above figures give the fraction of the schools which do not attain to that standard.

The hours from 151 to 300 may be excluded, on the ground that that amount of time is unreasonable, or not comparable with the standards mentioned. The most rational hours are between 101 and 150 which are found in New York State in 25.3 per cent of the public schools, 50 per cent of the private schools and 30.7 per cent all told; and outside New York State in 36.9 per cent of the public, 37.9 per cent of the private and 37.1 per cent of all the schools. These schools meet the standard of the Committee of Nine and exceed that of the College Entrance Examination Board.

Judged by the standard of the New York State Education Department, the public schools of this State more than meet the requirements, since all but 6.9 per cent show more than 50 hours devoted to the laboratory work. The syllabus, if it be correctly interpreted, sets a minimum standard. To accomplish satisfactory results in a laboratory course is a different question. As already mentioned this minimum seems altogether too low. No student can derive a suitable training nor gain a reasonable knowledge of the experimental part of the subject in 45 hours of laboratory work.

The College Entrance Examination Board and the Committee of Nine recommend a number of experimental lectures to illustrate laws and phenomena which demand the greater experience of the instructor for their successful demonstration.

In table 2 it may be observed that in the New York State public schools, to the extent of 58.2 per cent, no such lecture is given, 17.7 per cent show from 26 to 40 lectures, or about one per week. In the private schools 22.8 per cent show more than one per week. In 54.4 per cent of the schools outside New York State no lecture is given.

Table 2

Time spent in classroom

EXPERIMENTAL LECTURES	PERCENTAGE OF SCHOOLS					
	SCHOOLS IN NEW YORK STATE			SCHOOLS OUTSIDE NEW YORK STATE		
	Public	Private	Total	Public	Private	Total
0	58.2	40.9	54.5	52.6	58.7	54.4
1–10	11.4	4.5	9.9	9.2	13.8	10.5
11–25	10.1	18.2	11.9	10.5	10.3	10.5
26–40	17.7	13.6	16.8	19.7	6.9	16.2
41–90	2.6	22.8	6.9	8.0	10.3	8.4
RECITATIONS PER WEEK						
1	1.3	4.5	2.0	10.5	13.8	11.4
2	10.1	22.7	12.9	31.6	20.6	28.6
3	36.9	22.7	33.8	25.0	34.5	27.6
4	17.7	27.3	19.8	13.2	17.2	14.3
5	34.0	22.8	31.5	19.7	13.9	18.1

This data may be in error to a certain degree, for some of the teachers may have misunderstood the question. However, it can, at least, be stated that not over 23.7 per cent of the public schools in New York State and 24.6 per cent of the others give experimental lectures as often as once a week. Further, the lecture side of the course in 45.5 and 45.6 per cent, respectively, was not of sufficient moment to make any serious impression upon the teacher.

Evidently the experimental lecture is not popular. The full explanation is not exactly obvious although several reasons may be assigned. A considerable equipment is needed for lecture experimentation and this equipment is expensive. Then again, the teacher's time is pretty fully occupied with routine work and little or no opportunity is allowed for the preparation of lectures. It takes time to successfully prepare the apparatus for an experimental lecture, as all who attempt to give such lectures are well aware. Yet this is a fact which is not generally appreciated, for many an otherwise ambitious teacher is prevented from developing his course because he is required to be on duty in classroom or study hall when his value to the school would be better conserved if that time were spent in preparing lectures or arranging the laboratory.

In connection with the study of the data about the experimental lecture, it is interesting to notice that where the lecture was weak the recitation was strong. In 34 per cent of the public schools of New York State there are 5 recitations per week; over 3 per week in 51.7 per cent; and 3 recitations in 36.9 per cent. In all but 11.4 per cent there are over 2 per week.

The data from the private schools and from those outside New York State may be seen in the table. The schools outside New York State seem to favor few recitations and incline toward 2 and 3 per week.

3 Method of recording experiment

The method of recording the experiments falls, generally, into four classes. In many schools the printed manual is used and the student is allowed to write his record on the page opposite the directions. With care in its use it is possible to gain desirable results with this kind of a notebook, but the tendency is to record the work very incompletely. Usually the record consists of perfunctory answers to a few questions. The book itself, in whatever way it may happen to be printed, is of no moment in this discussion.

The second method of writing up the notebook may be called the tabulated form. The various headings, under which the student is supposed to write the details of the experiment and his conclusions, are written out or printed on the page which is then ruled in rectangles to be filled in as the experiment proceeds. The efforts of the student are thereby reduced to the minimum with the natural result that he does little work, and that poorly. The method is pernicious.

The topical method is the most common. The record is divided into the headings—Apparatus, Operations, Results and Conclusions. It differs from the preceding in that these headings are not ruled off on the sheet with the spaces vertically beneath, but are extended along the page in paragraph form. There are various modifications of this method. If not closely supervised the student easily drifts into the habit of using stereotyped phrases under the different headings. In all but few cases the notebooks of this form were not of a high order.

The fourth method is unquestionably the best. The record is written as a clear simple report. The subdivisions are those which the natural order of the experiment demands and are the paragraphs of ordinary English writing. Its advantage lies in the fact that the student is obliged to think connectedly while the report is written. More originality of expression is possible and the emphasis is taken from the operation and placed upon the clear exposition of the phenomena and upon the reasoning. Set expressions are avoided and the teacher may render more assistance to the student because the latter expresses himself more naturally. The method is applied in several schools.

4 Literary character of the record

The writing of clear correct English is a result for which the laboratory notebook affords an excellent training. The teacher of chemistry and the teacher of English should fully support each other. Drill in the application of a rule may be unpleasant to a student but with a little care on the part of the teacher the same rule may become an unconscious possession and be used in the writing of an interesting experiment. Teachers of English are often blamed because the students use the same bad English after their school days that they did before. It must not be forgotten that the responsibility rests equally at least upon the teachers of science who allow the use of expressions which were never learned in the classes in English. If the one teaches the theory of expression it is the duty of the other to insist upon the correct practice.

The frequent use of the first person was one of the common characteristics of the notebooks. Students are often urged by the teacher to use that form of expression. Yet it scarcely needs mention that they are thus confirmed in a habit which is avoided in all good writing. The substance, or the observation, may easily be made the subject of the sentence. It may require more effort at first to teach him to use correct expressions but he will thereby form habits of lasting value instead of those which in after years will need changing. The use of the first person in laboratory records should vigorously be condemned.

Simply bad English was all too common. The teachers evidently spend little time over the literary character of the reports. The fully written record, which has been mentioned, is conducive to the use of good English.

5 Scientific character of the record

The subject-matter of the record will not be discussed here, for it is outside the field of this article. The efficiency of the chemical training, however, is unmistakably demonstrated by the scientific character of the record. That is, the reasoning shown, the pertinence of the conclusions and the general quality of the work show how well the student is trained.

Prominent among the several striking features of the notebooks examined is that of the copying of directions from the manual in place of writing an original report. This fault is prevalent in the smaller schools where the apparatus for the performance of the experiments is not complete. It is obvious that the student who is allowed to record his work thus is more injured than helped by the study. He begins the habit of dishonesty for he thus offers as his own, work written by another.

Often an equation is made the aim and conclusion of the experiment with no semblance of connection between the observations and the equation. An equation has undoubted uses but should never be written by a beginner except after a full explanation. Otherwise wholly erroneous ideas as to the purpose of the equation, are inculcated.

Among all the notebooks reviewed the most recurrent error was the perfunctory writing of unsupported conclusions. An experiment is performed, observations made and conclusions written out but no sign of a reason to show how that particular conclusion was reached from the observations mentioned. Since a conclusion is demanded the student follows the directions and "concludes." Yet to render conclusions from insufficient data is to form one of the most vicious habits that can be formed. In preparing methane, for instance, the student could be honest with himself and write a fair exposition of the data as he found them and draw only those conclusions which are supported by the evidence. If it could not be ascertained that the gas was methane except from the teacher or from the reference work it would be far better to explain the experiment thus and so call attention to the presence of incomplete data. Many experiments do not afford the data for general statements and it is well, for thereby a valuable lesson in judgment may be learned. When the teacher allows the students to use superficial and stereotyped conclusions he aids in the formation of habits of thinking which render such study of chemistry of more harm than good.

Sharply distinguished from the above are those reports which are written up fully and carefully. Often the reasoning is full and to the point. The fact that several schools are able to produce such reports confirms the belief that it is quite possible to obtain satisfactory results which are well worth the time and energy expended. The educative value of chemistry depends quite as much upon the character of the teaching as upon the na- of the subject.

6 Special features of the laboratory course

Quantitative experiments have for several years been emphasized by teachers of chemistry. These experiments afford training in measurement and accuracy of observation and serve to verify the laws which the student would otherwise be obliged to accept as a matter of theory.

The proportion of the schools in which this work is given, is an interesting question. In table 3 the quantitative and the common physical experiments are classified so as to give the percentage of the schools which include the experiment in their course. The "distillation" experiment is that of the separation of a salt from water. Under "hydrogen equivalent" is included all forms of that experiment. By "ionization" is meant all those experiments which are intended to illustrate that theory. Under "miscellaneous" are included such experiments as the analysis of a carbonate for carbon dioxid. The "solubility" is the usual form of experiment to determine the approximate extent of the solubility of the common salts.

In all but four, viz, 1, 10, 13 and 14, the private schools give these experiments more generally than do the public schools.

Of the schools outside New York State the private schools exceed the public schools in all but seven of the experiments, viz, 1, 5, 7, 8, 11, 12 and 13.

Table 3

Quantitative and physical experiments

SUBJECT OF EXPERIMENT	PERCENTAGE OF SCHOOLS IN WHICH EXPERIMENT WAS PERFORMED					
	SCHOOLS IN NEW YORK STATE			SCHOOLS OUTSIDE NEW YORK STATE		
	Public	Private	Total	Public	Private	Total
1 Distillation	15.4	5.5	12.9	17.0	16.9	16.9
2 Hydrogen equivalent	9.5	33.3	15.7	12.8	25.0	16.9
3 Ionization	3.8	5.5	4.3	4.3	16.7	8.5
4 Law of def. prop'ns Na_2CO_3—NaCl	1.9	5.5	2.9	14.9	20.8	16.9
5 Metal+Oxygen	1.9	11.1	4.3	10.6	4.2	8.4
6 Miscellaneous	5.8	11.1	7.1	10.6	12.5	11.3
Oxygen						
7 Per cent in air	15.4	27.8	18.6	21.3	12.5	18.3
8 Per cent in $KClO_3$	11.5	22.3	14.3	10.6	8.3	9.9
9 Weight of 1 liter	3.8	11.1	5.7	6.4	25.0	12.7
10 Solubility	13.5	11.1	12.9	19.1	33.3	23.9
Water						
11 Decomp'n by electricity	23.1	27.8	24.2	23.4	20.8	22.5
12 H+O by eudiometer	3.8	5.5	4.3	6.4	4.2	5.6
13 H+CuO	5.8	5.5	5.7	12.8	8.3	11.3
14 Water of crystal'n	11.5	11.1	11.4	10.6	25.0	14.8

In all but three, viz, 7, 8 and 11, the schools outside New York State exceed those in this State.

In any event the number of schools in which this important part of the course is given, is small. Probably the figures would be larger if computed on the basis of a single experiment. A larger number would be found which do one experiment.

The results which the students obtained with a few of the experiments are shown in the next tables. Table 4 gives the results of the hydrogen equivalent experiment. The first five columns are from the work as found in the notebooks. No attempt was made to correct any errors in that work. In the fifth column, however, it was necessary to recompute the figures, in a few cases, to make them comparable with the other data. Such recomputed data are inclosed in parentheses. The entire sixth column is mine. Inclosed in parenthesis under the name of each metal is the value of the hydrogen equivalent computed from the atomic weight given in the report of the International Committee on Atomic ghts for 1905.[1]

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[1] Chem. Soc. Jour. 1905. 27:5.

Table 4

Hydrogen equivalent

ALUMINUM

(8.93)

	Weight metal	Vol. H c., c.	Vol. H corr.	Weight H	Equivalent	Percentage error
1	.06	70.3	64.8	.0058	10.3	15.3
2	.06	128.85	111.5841	.09997935	6.2	30.6
3	.52	605	518.09	.0466281	11.1	24.3
4	.08	120	106.4	.00953344	8.39	6.0
5	.0660	90	82.8	.00742	8.97	0.45
MAGNESIUM (12.1)						
1	.058	60.6	54.7	.0049	11.83	2.23
2	.41	420	381	.034	11.98	0.98
3	.089	84.5	76.8	.006912	12.87	5.8
4	.220	248.00	228.8	.02051	10.75	11.2
5	2	217	200.184	.01794	11.16	7.7
6	.026	25.6	23.29	.00208	12.5	3.3
7	.05	56	49.79	.0046	11.5	4.9
8	.3	370	310.25	.0279225	10.7	11.6
SODIUM (22.88)						
1	.906	462	438.3	.039447	22.967	0.39
2	.723	385	346.6	.03108	23.26	1.7
ZINC (32.45)						
1	.0257	102	92.5	.00829	31.0	4.5
2	.205	78.2	71.9	.006287	32.69	0.74
3	1	680	575.1	.0488	30.71	5.4
4	.23	92	80.8	.00723	31.8	2.0
5	.2	72.3	66.3	.00592	33.8	4.2
6	.2789	101	92.94	.008377	33.49	3.2
7	.1	37	33.2		33.4	2.9
8	.24	112	97.17	.0087	27.58	15.0

The table shows that poor work is done and that good work can be done. The results are evidently the individual work of the student and show no tendency in any particular schools toward any particular results.

From a consideration of columns 3 and 4 a somewhat interesting observation may be made. These columns give the calculations as they were carried out by the students. In only one instance was the metal weighed to four significant figures. In many cases the weight of the metal was expressed in two figures. Yet the calculations in columns 3 and 4 were carried far beyond the limits of experimental error. This is an absurd limit to which to extend calculations. It is better to carry out the computation only to the limit of the accuracy attainable in the experimentation. A training in judgment is afforded the student, if he be taught to choose in each experiment the extent to which he is to carry the divisions and multiplications.

Table 5 shows the results obtained in some other experiments. As before, the data in parentheses were computed by me. The first half of the last part of the table gives the percentage of oxygen obtained by taking the difference in weight between a crucible containing potassium chlorate before and after heating.

Table 5

Composition of water

H+CuO

	W't O	W't H_2O	Ratio H_2 :O	Ratio O:H_2O	Percentage error
			(1:7.94)	(0.888)	
1	0.42	0.48	1:7.0		11.8
2	.89	1.000	1:8.091		1.9
3	1.0	1.3		(0.770)	13.3
4	20.362	22.905	1:8.007		8.4
5	.111	.148		(0.750)	15.6
6	.91	1.03	1:7.58		4.5

METAL+OXYGEN

Magnesium

	W't Mg	W't O	Ratio O: Mg	Percentage error	
			(1:1.52)		
1	.52	.33	1:1.57	3.3	
2	.475	.30	1:1.56	2.6	
3	.29	(.15)	(1:1.93)	27.0	
4	.165	.109	1:1.51	0.6	
5	1.6	.87	1:1.84	21.0	

PERCENTAGE OF OXYGEN IN $KClO_3$

	W't $KClO_3$	Vol. O	Vol. O corr.	W't O	Per cent O	Percentage error
					(39.2)	
1	1.52	....	....	.61	40.1	2.3
2	1.75	....	....	.68	39.07	0.33
3	3.67	....	....	1.4	38.1	2.8
4	1.62	....	....	.52	(37.1)	5.4
5	1.37	....	....	.544	39.7	1.3
6	.3365	94.9	84.8	.1212	35.05	10.6
7	.25	51.4	47.2	.067	(26.8)	31.6
8	1.462	420	584.78	(.55)	(37.6)	4.1
9	.2	53.9	49.5	.08	(40.0)	2.4
	.326	95.7	88.905	(.127)	(39.0)	0.51

8 Conclusion

In conclusion, the course in chemistry centers about the laboratory work. The recitation and the experimental lecture have their special functions to perform but it is useless to attempt instruction in chemistry without a well equipped and adequately supervised laboratory.

All things considered, the total amount of time to be spent on laboratory work will depend to a certain extent upon the number of consecutive hours in the laboratory period. If the period is one and one half hours in length then two per week during 36 weeks will accomplish the desired results. Under such an arrangement the total number of hours for the year would be 108. However, if there be more than one and one half consecutive hours in the period it will be possible to accomplish the same results with fewer total hours.

The character of the notebook record is a matter of vital concern. The best work is done when the student writes a simple but full exposition of the important features of the experiment with whatever conclusions are to be derived therefrom, and renders it in clear English. It would be advisable to take only rough notes in the laboratory and write the connected report outside, or at least after the entire experiment had been performed.

Emphasis should be laid upon the use of good English in the record. The reasons for every conclusion should be fully stated and the experiment should be interpreted only so far as the conditions and data warrant.

Quantitative experiments are recommended and the calculations involved should be carried no farther than the limit of accuracy with which the weighings and readings are made.

If the students are well prepared, chemistry can be taught successfully in the high schools. To do so it is necessary to adequately equip the laboratory with desks and apparatus; to allow the students to work in periods of not less than one and one half hours in length; to arrange the teacher's time so that it will be possible to prepare experiments and to carefully supervise the laboratory; and for the teacher himself to be well educated and to keep alive to the developments of this progressive science.

SOME PROPERTIES OF MATTER AT LOW TEMPERATURE

BY PROF. J. S. SHEARER, CORNELL UNIVERSITY

One of the most important elements which influences man's physical existence is the temperature of his surroundings, the very maintenance of life being conditioned on a comparatively narrow temperature range. The change from winter's cold to summer heat undoubtedly gave to prehistoric man his ideas regarding limits of temperature variation, while acquaintance with fire, and in certain parts of the earth with volcanic eruptions and geysers perhaps gave an extension as regards the question of higher temperature. We are still, however, accustomed to consider any temperature as low which falls very much below the temperature at which ice melts even though our experience is now extended very considerably beyond that limit. The processes of manufacture which often demand the use of very high temperatures have enlarged our knowledge in this direction until they have become somewhat familiar to most observers. Yet, beyond the reduction secured by ordinary freezing mixtures, temperatures considered as low are by no means familiar to most of us. We may therefore assume that any temperature more than 30° on the centigrade scale below the freezing point of water may come properly under the definition of low.

The methods employed in the production of these temperatures may be divided into three distinct classes. By the addition of suitable salts to solids it is possible to hasten the process of liquefaction; the heat required to change from solid to liquid state being abstracted from the surroundings gives a temperature reduction. If we use, for example, various salts with ice in proper proportions the temperature of the melting mixture may be reduced to perhaps 20 or 30 degrees below the zero point depending upon the nature of the mixture. It is not, in general, convenient to use this process with many solids for various reasons. If, however, we choose a mixture of solid carbon dioxid and ether in proper proportions, a temperature of approximately −80° C. may be secured. Another natural process requiring the expenditure of heat consists in the vaporization of a liquid. The conditions under which vaporization continues are more or less under control, since part of the work done in changing a liquid to a gas consists in overcoming the external pressure which opposes the increased volume from the solid to the liquid state and a reduction of external pressure will facilitate the process of vaporization. Increased vaporization, however, demands expenditure of heat and if the process be maintained the temperature of both the liquid and its surroundings will be reduced by the continued change of state. If it were possible to secure a series of liquids whose boiling points were properly aced a series of controllable temperatures might be secured by boiling these liquids at varying pressures. By a combination of cooling with solid carbon dioxid and the application of pressure early investigators succeeded in liquefying certain gases which had previously been regarded as existing only in the vapor state, and by boiling these liquids under reduced pressure a still greater reduction in temperature was secured. It at first appeared to investigators in this field that since the conditions which determine the physical state of a substance are the pressure and temperature to which the body is subjected and since increase of pressure as well as reduction in temperature always tends to change vapors into liquids, it would be possible by a sufficient increase in pressure to change the most refractory gases into the liquid form. The researches of Andrews showed that such was not the case. He demonstrated that unless a gas be reduced in temperature below a point which is definite and fixed for each particular substance it would be impossible by any increase of pressure to change the material to the liquid state. For example, it would be absolutely impossible to liquefy carbon dioxid unless the temperature of the gas was reduced below about 34°C. This point, to which the temperature must be reduced before pressure can cause liquefaction, is spoken of as the critical point for that particular substance. It should be noted, however, that simple reduction of temperature would not necessarily produce liquefaction, since to each temperature below the critical one there corresponds a definite vapor pressure. The further the gas is reduced, however, below its critical temperature the smaller will be the applied pressure necessary to produce liquefaction. The critical temperature of oxygen, nitrogen and hydrogen is much below the lowest temperature attained by boiling ethelene and similar liquids under reduced pressure so that for many years these came to be named permanent gases and greater temperature reduction was required before they could be liquefied. Another process which results in lowering of temperature is the expansion of a gas against an external pressure. The process of compression of any gas results in the production of a rise in temperature while the same gas when expanded usually cools. By a combination of the processes above described Olzewski, Dewar and others succeeded in liquefying oxygen, nitrogen and air. The first plants arranged for this purpose were, however, exceedingly complicated and expensive. A few years ago Professor Linde of Germany and Dr Hampson, an English physicist, devised apparatus for utilizing continuously the cooling of gases by expansion from high pressures so as to produce temperatures much below the critical temperature for nitrogen or oxygen, in fact lowering the temperature to such a point that these gases would liquefy at ordinary atmospheric pressure. By exhausting the gas rapidly from the vessel containing these boiling liquids a still further reduction of temperature was available.

Let us now consider for a moment the question of probable limits of available temperatures. As regards the higher limit we are not likely to secure a temperature much above that of the positive carbon in an electric arc, especially when designed for electric furnace operation. This temperature has, in reality, never been measured by ordinary methods but is probably somewhere between three and four thousand degrees on the centigrade scale. Our idea of the lowest temperature which we might expect to attain is based on the supposition that the pressure exerted by a gas upon the inclosing walls reduces by $\frac{1}{273}$ of its value at 0° for each degree of temperature reduction. If then the gas should *remain* a *gas* and should *maintain* the same rate of pressure reduction as the temperature was still further decreased we should expect that at a temperature of –273 the gas would be incapable of exerting any expansive pressure whatever. This supposition is not one which is warranted by our experience with any of the common gases since they all change from the gaseous to the liquid state at ordinary pressures before a temperature approximately of 273 below zero is reached with the exception of the rare gas helium. A picture of the range of temperatures below zero degrees may be shown by measuring a string 273 units in length as attached here to the ceiling and considering the point of attachment as zero on the centigrade scale. The first tag attached corresponds to carbon dioxid mixed with ether, or – 80°C. The next corresponds to the critical temperature for atmospheric air very approximately 130° below zero. The next is the boiling point of oxygen – 182.4 and slightly below that the boiling point of nitrogen – 195.6.

The next step in the development of low temperatures was one which required careful consideration and a further application of the methods which have already been mentioned. The critical temperature of hydrogen is lower than can be attained by the boiling of nitrogen under reduced pressure, that is, much lower than – 210°C. (This temperature has recently been determined and is very closely – 240.8.) The Hampson process of liquefaction has been successfully applied not only to the case of oxygen and nitrogen but also to the case of hydrogen, and because of its simlicity and effectiveness it is coming to be regarded as the standard method for the liquefaction of gases having low boiling points. The general principle of the apparatus may be illustrated as follows:

Suppose we consider a long metal tube having an adjustable valve at one end and connected at the other with a powerful air compressor capable of supplying a considerable quantity of air at a pressure of 3000 pounds a square inch. If the valve at the end of our pipe be opened, expansion to atmospheric pressure will entail a reduction of temperature. This temperature reduction, however, will not be extremely great and would be largely neutralized by the inflow of heat from the surroundings. Suppose, however, that the tube is insulated as far as possible from all heat supply and is inclosed in a second tube so that the gas partially cooled by expansion passes back on the outside of the first tube, regaining its temperature by absorbing heat from the tube conveying the incoming gas. In this way the gas at the expanding nozzle will be gradually reduced in temperature until finally it comes below the temperature at which liquefaction will take place at atmospheric pressure. As a matter of convenience in installation and operation the tube carrying the gas is wound up in a spiral coil and is carefully protected from external heating by a suitably constructed jacket. Such a liquefier will operate successfully in the case of air without preliminary cooling but in the liquefaction of hydrogen the gas under pressure must be cooled somewhat below −80°C. before liquefaction can be produced. The effective cooling is due to the slight mutual attraction of gas particles, i. e. to the Joule-Thomson effect.

The measurement of low temperatures can be accomplished by the use of gas thermometers, thermo-elements, resistance thermometers or by the use of certain special liquids whose freezing points are extremely low. For the lowest temperatures now attainable, however, a helium gas thermometer or a properly constructed thermo-element is the most practical.

Undoubtedly one of the most interesting substances at low temperatures is air in liquid form. We have in this small beaker a nonviscous pale blue liquid whose density is approximately unity as is readily shown by pouring some on the surface of water and observing the immersion. The surface tension of the liquid is small and the temperature of this particular specimen is probably very close to −188° on the centigrade scale, the temperature varies according to the relative proportion of oxygen and nitrogen in the mixture. The density also varies with the composition from 1.31 for oxygen to .791 for pure nitrogen. Liquid oxygen is slightly magnetic as may be shown by observing the attraction of a small horseshoe magnet for the liquid. Liquid air, oxygen or nitrogen behave precisely as other liquids excepting that they happen to have boiling temperatures at atmospheric pressure very much below those to which we are ordinarily accustomed. The behavior of liquid air when poured upon a surface at room temperature is exactly the same as in the case of water placed upon a surface extremely hot as compared with the boiling point of water. A layer of gas is developed between the hot plate and the cold liquid which forms a cushion preventing actual contact between the two. If we pour liquid air upon a small glass in the vertical projection field of the lantern we will note that it vibrates quietly for some time without any sputtering or hissing until it finally comes in contact with the glass when it boils much more violently. In common with all other liquids, liquid air has a definite heat of vaporization and it requires the expenditure of approximately 51 calories of heat to convert one gram of liquid air at its boiling point to gaseous air at the same temperature. If we consider the specific heat of air as constant between its boiling point and 0°C. the total heat required to convert 1 gram of liquid air at its boiling point to ice cold air would be very nearly 95 calories.

In order to keep the liquid it is necessary to construct vessels which will prevent acquisition of heat, since if the heat of vaporization is not supplied the air will retain the liquid form. The most successful vessels for this purpose were invented by Professor Dewar of the Royal Institution, London, and are known as Dewar bulbs. They are constructed of glass instead of metal which prevents the conduction of heat from the surroundings. They are made double walled and the air between the two walls is removed so as to prevent the transfer of heat from the outside to the liquid by conduction or convection of the gas and finally they are frequently coated with a layer of silver which serves to reflect radiant heat and light, thus very effectively preventing heat transfer to the liquid.

Since no pressure, however great, would keep air liquid at a temperature above − 130°, vessels containing liquid air must not be tightly closed. Pouring a small quantity into a piece of heavy rubber tubing and closing both ends the pressure developed on evaporation is readily shown.

By the use of liquid air as a cooling agent it is possible to liquefy many gases at comparatively low pressures. Taking a tube containing ethelene which in the field of the lantern is apparently empty, and immersing it for a moment in a bath of liquid air, we find that we have an accumulation of liquid 1 or 2 cm. deep in the bottom. Were the earth to be cooled to a temperature of −195°C. we should have a layer of liquid upon its surface approximately 35 feet in depth with various solids not especially familiar to us such as solid CO_2, ethelene, etc. floating therein.

If we consider the effect of great reduction of temperature upon liquids, we find that at the temperature of liquid air, mercury, alcohol, ether, chloroform etc. have become solids. A test tube filled with mercury gives us a solid which will persist for a considerable time after removal from the liquid and which you see is malleable and not unlike soft lead in appearance. Certain liquids such as pentane and petroleum ether have freezing points below the temperature of liquid air and may therefore be used in thermometers for low temperature measurement. If we take ordinary coal gas and pass it through a tube immersed in liquid air and observe the character of the flame at the opposite end of the tube we will note that its luminous qualities are greatly reduced ultimately giving a flame which chemists would recognize as characteristic of burning hydrogen. Cutting off the gas supply and removing the tube from the cooling liquid we observe that a considerable amount of solid material is present in the bottom of the tube and on the application of heat this solid material changes to a combustible vapor which may be lighted at both ends of the tube, giving a highly luminous flame. Liquid air contains a higher percentage of oxygen than ordinary gaseous air owing to the fact that the boiling point of oxygen is higher than that of nitrogen and consequently a greater per cent of the oxygen liquefies than of the nitrogen. This fact may be shown by observing the ability of vapor from an old sample of liquid air, which has become still richer in oxygen by the more rapid vaporization of the nitrogen, in which ordinary wool burns with explosive violence. Saturated charcoal behaves on ignition very much as gunpowder.

When we come to consider the effect of reduced temperature upon solids we may say that brittleness, rigidity and tensile strength are in general increased. If we take a small coil of fuse wire incapable of supporting a given weight at ordinary temperatures and retaining its spiral form we find that upon reducing to the temperature of liquid air the weight is readily sustained and we may note the gradual straightening out of the coil as the temperature rises. Flowers, beefsteak and pieces of rubber become extremely brittle at these temperatures, a piece of rubber tubing having elastic properties similar to a piece of glass.

A further peculiar effect may be noted with regard to ability of bodies to store up luminous energy and give it out as light after the exciting source has been removed. Take for example, an egg which has been subjected to liquid air temperature, also a piece of paraffin candle and a tube of solid alcohol and expose them for a moment to the radiation from an arc lamp and then observe them in a dark room. Each glows with a characteristic phosphorescent light. The egg especially gives a beautiful wavering blue color. It might be of interest to observe in this connection that liquid air like ordinary air is a good insulator and that we may have in the same small beaker simultaneously one of the highest and one of the lowest temperatures conveniently attainable by operating an electric arc beneath the surface of liquid air. Notice that the arc is extremely brilliant and is maintained without serious difficulty.

I wish to call your attention to the fact that the temperatures here exhibited are by no means the lowest which have yet been attained. The following table may be useful as giving certain important temperature points for reference.

Solid CO_2+ether	−79.8°C.
Boiling oxygen at a pressure of one atmosphere	−182.4
Boiling nitrogen at a pressure of one atmosphere	−195.5
Boiling O at a pressure of one mm of mercury mm	−228
Critical point of air (approx.)	−130
Critical point of H	−240.8
Boiling point H	−252.5
Melting point of H	−257
Lowest temperature attainable by use of H (estimated)	−260
Lowest temperature as yet actually measured	−258.5
Estimated temperature by expanding helium cooled to −258°	−266.5

I wish you particularly to note that all of the phenomena which you have seen in connection with low temperatures are similar to those open to observation on various substances at ordinary ranges of temperature. In fact there is nothing contrary to ordinary experience in any of the properties of matter in this interesting field. When first asked to speak to you upon this topic I was strongly tempted to decline because of the sensationalism which has been developed in connection with this topic as well as many others in physical science. A few years ago the unscientific public and many supposed scientific men were greatly enthused by lyceum bureau lecturers on this wonderful liquid and by magazine articles written by a promoter who succeeded in floating stock of a concern for the manufacture of liquid air. The intense desire of the American public to make money by getting something for nothing was seized upon by the promoter to further his own ends by stating that when once started the liquid was self-producing and picturing in glowing terms the tremendous possibilities in the development of power. It is perfectly true that an enormous pressure may be produced by applying heat to liquid air in an inclosed space. But this gives no indication whatever concerning the energy relations involved and liquid air has not proved in any way an exception to the fact that work must be performed in order to get returns. Not only this but even conservative speculators were imbued with the idea of utilizing this exceedingly cold liquid as a refrigerating agent. A party not 1000 miles from an institution where accurate information regarding the properties of this liquid might have been obtained lost about $60,000 in efforts to utilize liquid air for refrigeration purposes. Note that a refrigerating temperature below zero degrees is seldom required in practice and that for this limit 80 lb of liquid air will be very approximately equivalent to 95 lb of ordinary ice. Under the conditions of operation in the plant where this air was obtained the cost of production comes pretty close to $4 a liter including breakage of expensive containers, interest and depreciation, attendance etc. It is hardly to be expected that refrigerating plants utilizing this liquid would be financially successful.

It may naturally be asked what is the use of liquid air and of low temperature investigations. As far as the scientific man is concerned increase of knowledge of nature pure and simple is a sufficient excuse for the expenditure of money and time to any extent. Even to those who unfortunately look only at immediate commercial returns we may still say that this liquid has proved to be of considerable use and to two cases I especially call your attention. In the preparation of oxygen for medicinal purposes the evaporation of liquid air gives a product much less likely to contain poisonous materials than that obtained by most chemical processes. Another application which may appeal very directly to some of you at some time of your life, is in the production of chloroform for use in anesthesia. It has been found that the presence of impurities in chloroform add very greatly to danger to life in its use and the only way in which perfectly pure chloroform can be practically produced is by freezing out the impurities by the use of liquid air as a refrigerating agent.

In conclusion I wish to urge upon you one and all as teachers to beware of sensationalism and *yellow* science. While maintaining an open mind regarding physical theories and admitting possible limitations of so called natural laws you, of all mankind, should stand firmly for the general results of sound scientific experience and not eagerly seize each passing will o' the wisp which the public, still influenced by superstition and mysticism, fondly hopes will, miraculously, enable them to violate natural laws with impunity. How often in the last few years have even reputable magazines joyfully announced the final overthrow of that barrier to the realization of mystic hopes, the conservation of energy. Liquid air, self-regenerating, to drive our flying machines for nothing. Radium overthrowing all the ponderous laws of physical science and to be not only the inexhaustible storehouse of thermal energy but also the long sought fountain of youth and cure for most diseases. And not a little of this sensationalism is due to those who should be high priests at the altar of truth instead of demagogues selling their birthright for the miserable pottage of popular excitement. The world has a right to expect that teachers and investigators in science should live up to the highest scientific ideals and if the educational results of science do not always compare favorably with those of the subjects it has displaced is it not largely due to our failure to realize its real dignity and power? Do not imagine for a moment that I believe physical science should not be made attractive or that striking experiments may not be legitimate and useful. Is it necessary to surround science with mysticism or to teach what the ripest results of experience contradict in order to create a transient wonder and to keep up interest in our chosen subject? One who in any small degree comprehends the real wonders of our environment, the subtle beauties of the simplest natural process, visible to those who, having eyes, really see, can hardly fail to be an attractive teacher even though building no air-castles to obscure the temple of truth. To develop sound appreciation of science, to increase its usefulness in daily life, to make it satisfy the highest intellectual cravings and finally to dispel the idea of a vacillating and uncertain mystic ruling power whose laws may be circumvented at will is the high calling of each and every real teacher of science.

SOME CHEMICAL EXPERIMENTS TO ILLUSTRATE THE NEW YORK STATE SYLLABUS FOR 1906

BY JOHN F. WOODHULL, TEACHERS COLLEGE, COLUMBIA UNIVERSITY

1 Generate oxygen and burn carbon and sulphur in it.
2 Burn iron in oxygen and show the product.
3 Find the percentage of oxygen in the air.
4 Find relative kindling temperature of illuminating gas, carbon, and sulphur. Miners safety lamp.
5 Burn illuminating gas in air and air in illuminating gas.
6 Produce hydrogen from sulphuric acid by zinc.
7 Collect 8 ounce bottleful of hydrogen from water by sodium.
8 Collect 8 ounce bottleful of hydrogen from water by hot iron and steam.
9 Decompose water by the electric current and measure the proportion of hydrogen and oxygen produced. 6 dry cells (1900) 4 volt, 2.5 amperes.
10 Produce water from hydrogen and hot copper oxid. Proportions *by weight* of hydrogen and oxygen in water.
11 Show the proportions *by volume* in which hydrogen and oxygen unite by exploding a mixture of them.
12 Prepare chlorin and burn antimony in it.
13 Prepare hydrochloric acid and test it for hydrogen and chlorin.
14 Prepare hydrofluoric acid and etch glass.
15 Prepare iron sulphid by burning together iron and sulphur.
16 Prepare hydrogen sulphid and show its reactions with salts of lead, zinc, arsenic and antimony.
17 Prepare nitric acid by the action of sulphuric acid upon potassium nitrate.
18 Prepare nitric oxid and nitrogen peroxid.
19 Prepare nitrous oxid.
20 Prepare ammonia.
21 Show by means of hot carbon that lead oxid contains lead and carbon.
22 Show that mercury oxid contains mercury and oxygen.

SOME PEDAGOGICAL PHASES OF SCIENCE TEACHING

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There is no teacher on the staff whose position is regarded with more respect than the teacher of science. To the popular mind he appears as the one member of the faculty who deals with practical affairs and the one who is expected to keep accurately posted on all the latest discoveries and their latest and practical applications to the affairs of mankind. Consequently he is freely consulted as an expert. His opinion is eagerly sought regarding the merits or defects of a new invention or a labor-saving and money-getting industrial process. Doubtless every mineral in the geologic horizon, having a noticeable weight, color, or luster has attracted the eye of some longer for wealth, who has seized and cautiously concealed a choice bit of the alleged precious mineral and bringing it to the local science teacher, expectantly waits with hushed breath until the fatal words regarding the find are pronounced. But it is not simply for the identification and estimation of the value of minerals that the science teacher exists in a community. He is perhaps a microscopist to whom the lawyers bring wills, promissory notes, and other valuable documents with signatures suspected of having been forged and the man of science is called upon to determine whether there have been erasures, bleaching, or alterations. Perhaps it is the district attorney or the coroner who brings a bloody coat and asks the science man to ascertain whether the blood is that of a hen or that of a fellow-man. Farmers bring well water for the testing of its potability. Physicians bring him the contents of stomachs and the like for analysis and before he realizes it the teacher of science has become an expert, testifying in the court room. Perhaps his fame as a mechanician spreads sufficiently so that instruments of precision are brought to him for repair—a barometer is just a little out of "kilter," an ammeter needs adjustment, etc.

What should the science teacher do with all of these calls from an asking public? If he devotes too much time to them, he must needs neglect instructing the youth. If he refuses all of these demands, he not only loses income but in some cases he fails to seize opportunities for his own mental enlargement. He also may lose caste with the public and therefore with his pupils and hence will soon lack that influence and prestige so much desired by a teacher. The fact that the teacher is sought after by the adult members of a community in the same professional way that physicians, lawyers, and other professional men are sought after, is to the mind of the growing student such an exaltation of the value of science and of the person who teaches it, that it lends itself immediately as a powerful incentive to increased interest and to harder study on the part of the student. The teacher who can wield such a magnet of influence over his scholars becomes the pride, if not the envy, of his coworkers on the faculty, and at the same time advertises his school in a legitimate way. A careful discrimination must be made regarding the character of the outside work undertaken. It should never be belittling, nor accepted wholly for the financial income, but always should tend toward the teacher's growth and be along the line of his particular subject.

The appreciative public is not alone in asking help. In many schools the science teacher is expected to do everything connected with material things about the premises that the janitor can not or will not do. No one is, for example, supposed to know how to operate the school mimeograph except the science teacher. In one school I visited a long time ago, I found the science teacher not only doing all of the mimeographing, but also operating a foot-power printing press, running off examination questions, daily program cards, and the like. While visiting another school in a near-by state, the poor overburdened teacher of science was at his wits end, on a cold cheerless morning, trying to make a complicated system of electric wiring for recitation bells work properly. The system, if it may be called such, of bells was energized from a central battery of about 20 cells located in a dusty, dark place, far out of easy reach under the stairs. The science teacher was in that grewsome place on his hands and knees trying to locate the trouble. The principal was expecting that the bells would work immediately. The science teacher had installed the affair and was of course counted on to keep it going. He was doing his best. While he groped under the stairs, his class waited in the classroom. He had several pupils working alone in the physics laboratory, and there were some more green pupils in the zoologic laboratory who had encountered a difficulty and were now pursuing him with questions as to how to extricate themselves. To add to his other tribulations he had a visitor. In another school, I am told that the science teacher, having some gifts along manual training lines, is called on to make bookshelves, blackboard erasers and the like.

In far too many schools there is such a local and unholy reverence for homemade apparatus, that it becomes the painful duty of the science teacher to make, and usually without proper facilities for so doing, the meager and doubtless only apparatus he obtains.

What is the outcome of all this? Is the school injured or benefited by such work? Is it really a good investment of public money? Does not the science teacher get more for his labor per hour than the printer, the bell-wiring electrician, the carpenter, or the mechanic? If the science teacher is a teacher, let him *teach*, if not, let him resign and do something else. It is a mistaken policy on the part of the governing board that allows such a state of things to continue. True, there are some things outside the classroom that the science teacher can and ought to do. Very properly may the operation of the stereopticon for lectures be within the jurisdiction of the science teacher, but when it comes to making the school ink by the barrel, for use in the entire township and making all the disinfectants used in a system of schools, it is about time the too immediate applications of science be withdrawn.

It may be argued that it is inconsistent for one to hold that the teacher should do work for outsiders and not do these extras about the building, especially as the latter plan will save money for the school board and the benefits appear more immediate. Let us bear in mind continually that the science teacher is and should be employed by the authorities on account of his professional qualifications to do the work of a teacher and that he is in no wise to be considered as an employee hired to do general repair or building maintenance work. The teacher's main duty lies with the minds of the students, and is not that of an auxiliary janitor. Nor should the teacher be in active competition with the school supply houses. There is now no more call for the teacher to make the apparatus than there is for his printing and binding the books or for making the pens used. Better and in the long run cheaper apparatus can be purchased than can be made by an overworked teacher. I grant you that special and new apparatus must be constructed by the teacher, but there is really no excuse for making the stock pieces.

The maintenance and care of a laboratory demand about all of the spare time of the teacher. One seldom finds a laboratory equipped with either sufficient apparatus or apparatus of the right kind to fit any published laboratory manual and as a result a manual must be either compiled or written anew. Sometimes, much against his own inclination and always to his own astonishment, the science teacher discovers suddenly that he has become an author, whose work must constantly be revised, rearranged and brought up to date in order to meet changing requirements of the State and the colleges.

Permit me now to point out some of the errors apt to be made in the teaching of science. Let it be clearly understood that what follows is not intended as a recital of grievances but a list of obstacles to be overcome by him who would succeed.

No other branch of knowledge demands in the teaching of it the experimental work which is inseparable from the difficult subject-matter. Therein lies the danger of too much experimenting, and too little theory of which every experiment is only an illustration. Careful preparation in the theoretical knowledge must be given in order that the pupil shall understand clearly the details and object of the experiment. We take too much for granted, and assume that the learner understands and so we are amazed whenever a thorough cross-examination or a searching written examination reveals the fact that nothing at all has been taught—I say *taught*, for there is no teaching where there is no learning. Let us emphasize the theory, and let us increase the classroom drill whenever new experimental work is added. Very proper it is for us to endeavor to secure the research attitude on the part of the learner. We are fond of our special claim to the synthetic method of teaching. But let us remember that even these valuable pedagogic aids are liable to misuse. As a matter of fact we no longer compel the students to learn by original research *all* of the accumulated knowledge of the past centuries. It is indeed well that we do not try to do that. The idea that science teaching consists of nothing but experiments for the purpose of developing facts is scarcely held to be good nowadays.

With the introduction of individual laboratory practice for the pupil, there has arisen a consequent division of labor for the teacher. It is now common for many secondary schools and for most of the larger colleges to have teachers whose whole work is in the laboratory, supervising the individual laboratory work of the learners. The duties of these laboratory instructors are large and important, especially if the notebooks are carefully examined and criticized; and unless this work of laboratory instruction and notebook correction, burdensome though it be, is well performed, the laboratory for students might as well be closed once for all. It takes a keen eyed, farsighted and tactful teacher to superintend a class in physics and see to it that the pupils derive their results independently and that reasoning, and not imitation, or something worse, is employed. The teacher in the lecture room is the one to expound the theory, and in advance of the student's work in the laboratory, at least for the secondary school student, although we usually claim otherwise. Ordinarily this teacher acts not only as lecturer but also as drillmaster. Where there are several teachers instructing the same students, on what might be called the instalment plan, the danger is that there will be no continuity of instruction so essential to good teaching. Logical sequence in taking up the subjects taught and close association between the theory, experiments and drill and book work are fundamentals for success. Let the pupil first hear the instructor present the new material; let him see the accompanying experimental demonstrations; let him go into the laboratory and do the same or other similar experiments and record his results and have them criticized; let him read what the book or books say on the subject; let him be quizzed and thoroughly cross-examined on all of the work in its various ways of presentation and then he is ready for another topic.

While we are exalting the laboratory, let us not forget that other valuable auxiliary—the library. Let us not lose sight of the fact that one of our objects in teaching is to guide the students to the use of the library, which most of them will use far more than the laboratory, when they pass beyond the limits of our domains.

The time is gone by when all of the brightest students were skilfully slipped into the classical course and forwarded to college without a touch of science in the secondary school and when the science teacher had the intellectual riffraff, the scum if you please, of the school for his portion. This changed condition has been brought about very largely by the recognition of science as an entrance requirement for college. There is now scarcely a college in the land so backward as not to allow at least one science as an entrance subject. That science is destined to occupy a yet larger place in the curriculums of secondary schools is certain. The dangers of premature specialization are no longer imminent. Any pupil who leaves the secondary school without having studied at least one science is not broadly educated. Any college that demands three languages among its entrance requirements and will not accept science is fully as narrow as the one that requires three sciences and will not insist on at least one language. To have broadly educated secondary school graduates, they must have taken a course of study that is at least diversified and representative. The secondary school teacher is not only teaching for the school beyond, but also is teaching in the last school most of his scholars will ever attend. His aim is thereby broadened. His responsibility is therefore enlarged. It is he who should personify, in the eyes of his pupils at least, the very highest product of scientific training, in truth the very culmination of scientific civilization.

Let me close with two quotations along this thought. Berthelot, the great French chemist, recently called our attention to an important idea—"the difference between the modern era of applied extending over the last three quarters of a century, and the whole development of the human race during the last 6000 years or more: a difference so marked [he points out] that a new man is being created on a new earth, and the entire social organization is being transformed amid conditions for the comprehension of which the past offers no suggestive precedents or data." This being true, the schools have a duty to perform in making preparation for this change. It seems to me that Meikeljohn, the eminent English educator, fully solves this pedagogic difficulty when he says "it is useless to force this or that idea, this or that piece of knowledge on the minds of our pupils: all we do must be tried by the ultimate test—the test of life. This test is contained in the plain questions: Are the pursuits and the exercises employed in my school likely to be carried on by my pupils after they bid me good by? Will the habits I have given them remain? Are the ideas I have given them seeds that will grow and produce fruit for them in their adult life? Have I, above all, given them 'the expansive joy of soul over work' that is the source of all fine art?" If the results are affirmative, then our teaching is successful.

Section B—BIOLOGY

THE TEACHING OF BIRDS FROM THE ECONOMIC STANDPOINT

BY J. M. JOHNSON, MORRIS HIGH SCHOOL, NEW YORK CITY

Until very recently biology in our schools, and in many of our colleges has been taught with the view of giving the student a very general knowledge of life and its processes together with a training in scientific methods and scientific thinking. Only in a few of our colleges and in our agricultural schools has the economic side of the subject been emphasized.

Although the value of biology from the standpoint of pure science justifies its place in schools, yet we can, I believe, make it a far more valuable subject by giving much more emphasis to its practical side. In fact, the subject from the dollars and cents standpoint is capable of doing the nation more good than almost any subject taught unless it is the three r's.

The people in the past had come to believe that the resources of the country were inexhaustible; that forests could be cut and burned without stint; that our tillable land had almost no limit; that we could not exhaust our supply of fresh-water fish; that our fur-bearing animals could supply our wants for an indefinite time; and finally that birds were of no use anyway, and if they were, were so numerous that they could be slaughtered without number.

That time is past. We are rapidly waking up to the fact that we must plant where we gather, and must replace where we kill. Our resources are *not* inexhaustible. In the short space of about 100 years we have exhausted some, and others are rapidly nearing that point. Already our fur-bearing animals south of the Canadian line have gone. We are clamoring for free trade in lumber with Canada, because our supply of some kinds is so scarce. Our birds have decreased 40% in 15 years.

It is right here that we, as biology teachers, have a chance to do an immense amount of good, if we only will. We may educate legislators all we will to pass good laws, but without an educated public opinion it will result in little good. We are the makers of public opinion to a very large extent, and we must improve our opportunity in teaching biology from an economic point of view.

Until recently people have regarded birds as of little value except as ornaments to nature or to hats. We know now, however, that they are of immense value from the economic standpoint

Since this value is indirect, it is of special importance that the subject be carefully brought out in our teaching.

I shall endeavor in the short time at my disposal to give you some idea of what seem to be the important points in such teaching. The plan followed in our school is more adapted for schools in large cities than in smaller places. For the latter I should advocate the formation of bird clubs for observing birds in their natural surroundings in addition to the work here outlined.

The bird talks are given toward the end of the second half year when the pupils have studied some form of vertebrate, and are in condition to appreciate the position of birds in organic life.

The American Museum has loaned mounted specimens of about 20 birds representative of the different main groups. These attract the attention of the pupils at once, and increase their interest. Mounted specimens are better than slides for a small audience, as they give a better idea of the size and coloring of the bird.

The birds are then grouped into four divisions mainly in accordance with their food, namely: (1) birds of prey, (2) seed eaters, (3) insect eaters, (4) game birds.

Next the value of birds is discussed from two points of view: (1) The esthetic standpoint is briefly touched upon in showing the pupils that birds add to the beauty of the world, because of their colors, form and song, and that they add greatly to our enjoyment of spring and summer whether we know the different kinds or not. (2) The economic side of the question is then taken up in considerable detail.

The value of hawks and owls as rodent destroyers is shown by citing an illustration from Pennsylvania as follows: In 1885 the Legislature gave a bounty for the killing of hawks and owls, and in one and one half years 128,571 birds were killed for which $90,000 was paid. The value of the poultry saved was $1875. On investigation it was found that each hawk and owl destroyed on the average 1000 field mice each of which would do at the lowest estimate 2 cents worth of damage per year. The amount of damage done to crops in the year and one half by the killing of the birds was $.02x1500x128,571=$3,857,130. Add $90,000 to this and we have $3,947,130 as the amount of money it cost the state to save $1875 worth of poultry. This led to the repeal of the bounty law.

Birds as noxious weed destroyers are next considered. Birds of this character are the sparrows and finches, examples of which are shown to the pupils.

The effect of the tree sparrows on the weeds in Iowa is cited as follows: There are 10 tree sparrows to every square mile of that state. By an examination of the stomachs of these birds the average weight of seed eaten per day can be estimated. Multiplying this by the number of days the birds stay, this by the number of birds per square mile, and this by the number of square miles in the state, and we have the great total for one state of 1,750,000 pounds or 875 tons. The pupils are asked to consider what the number of these seeds must be; what the effect on the crops would be, if a large proportion produced weeds, and what it would cost the farmer if he tried to keep them out.

The most emphasis, however, is laid upon birds as insect destroyers.

Every year about $400,000,000 of crops are destroyed in the United States by insects alone. Birds of nearly all kinds eat insects at some time in their lives, and a large proportion feed almost altogether upon them.

The cotton-boll weevil does damage to the amount of between $10,000,000 and $25,000,000 a year; the cinch bug does millions of dollars damage to wheat; and the codling moth injures apples, pears and other fruits to an enormous extent. The gipsy moth has cost Massachusetts several hundreds of thousands in a few years.

The cuckoo is cited as an example of how rapidly birds destroy insects. In the stomachs of 46 black-billed cuckoos were found 906 caterpillars, 44 beetles, 96 grasshoppers, 30 stink bugs, and 15 spiders, making 1091 in all. The European jay fed one half million caterpillars to their young in one season. Many other examples are also given.

After showing the value of birds, the need of protecting such useful animals is then shown.

Birds have decreased in 15 years 40% in the United States, varying from none in three or four states to 15% in Massachusetts, and 70% in Florida. The reasons for this decrease are: (1) the use of birds for millinery purposes; (2) the unlimited slaughter of game birds; (3) the wanton killing of birds and robbing of nests by boys and men, (4) the great increase in the number of cats with the settlement of the country.

375 gulls were killed by one man in one day and 375 more during the remainder of the week. 1000 small birds have been caught in a single net in California. 30,000,000 birds are used in Europe annually. All this for millinery purposes. Country and suburban cats average about 60 birds each per year. Game birds are killed

in spring so that the chance for normal increase is greatly diminished. Sea birds' eggs have been collected for eating in great quantities. Many species were in immediate danger of extermination until the Audubon Society began their all important work of bird protection, and the United States Department of Agriculture began the sending out of reports showing the great danger to crops if the destruction was not stopped.

The question naturally occurs to the pupil, "What has this to do with me? I do not know one bird from another."

If the school is a mixed one—and we are assuming that it is—the teacher should urge the girls not to wear the plumage of any wild bird on their hats either as whole birds or as separate feathers, and to use their influence with their sisters, mothers and friends not to do so. They should be led to see that the women wearing such feathers are beginning to demean themselves in the eyes of other people. The use of *egrets* should receive special attention as these birds are all but extinct in this country. If they *must* wear *feathers*, let them be encouraged to wear ostrich plumes and other domestic fowls' feathers.

Even in a city school many of the boys go into the country for the summer. They must be encouraged to try to study the birds alive, and not on any account to kill them or collect their eggs, and to use their influence for bird protection. Some fear of the law should be held before them, but the emphasis should be laid on the value of the bird.

The cat question may be touched upon. The pupils must see the danger to the birds from this source, and be encouraged to kill all superfluous cats in their own home, and homeless stray ones.

They should be encouraged to hunt only in the right season, and to obey the game laws in letter and spirit.

Finally every pupil must be made to see that for every bird killed, their parents and eventually they themselves will have to pay more for their flour, their clothing, and their fruit, because the killing of birds enables insects to increase, and if crops are smaller the consumer must pay more for what he uses.

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RESEARCH AND GRADUATE WORK FOR TEACHERS OF BIOLOGY IN HIGH SCHOOLS

BY ESTHER F. BYRNES PH.D. GIRLS HIGH SCHOOL, BROOKLYN

As we are teachers who have gathered together to discuss various phases of our professional work, I think that the subject on which I have been asked to speak, Research and Graduate Work for Teachers of Biology, must fall under two heads.

First, the value of close contact with the subject-matter of the science to the teacher himself; second, the influence of the teacher's relation to his subject, on those whom he instructs.

To those intimately acquainted with the science of biology, it is known to be, more than most subjects, a rapidly growing field of knowledge, and I think that there is a justifiable conviction that the interests of biology are in the vanguard of modern thought.

Within the limits of this field there are many lines of interest, each demanding its own methods of investigation and yielding results that though often illuminating, are as often varied and perplexing, and all are set forth in a cloak of terms so technical as to convey little meaning to the layman, without interpretation. But one common interest underlies all of these many fields of effort, namely, the reduction of unexplained phenomena in the organic world—in a word, evolution.

In 1877, Professor Huxley wrote, "Evolution is established; it is only the nature of the physiological factors to which that evolution is due which is still open to discussion." Let us examine this doctrine of evolution from the point of view of the contributions that have been made to the explanation of its methods within the past 50 years. In Professor Huxley's day the great contribution was Darwin's theory of natural selection; at first discredited as incompatible with accepted and enshrined beliefs—now universally accepted among those who care to be informed, as one of the factors in organic evolution.

Following Darwin, the wonderful revelations made by the microscopic study of the cell grew into a body of knowledge that when formulated, found expression in Professor Weissmann's *Continuity of the Germ Plasm* as a contribution to the solution of the method of evolution.

More recently the modern spirit of experimentation has discovered a new approach to the solution of the method, and has also discovered that even its method is not new. Today, this method is expressed in a single word "Mendelism," and one of the most modern phases of biologic research is the attempt to correlate cell phenomena with the results of experimental studies in the rearing of animals and plants.

Pasteur disproved the old theory of spontaneous generation. Today, we have the science of bacteriology with "radiobes" at one end of the series, and the bacteria of dairy products and the whole field of germs in their relation to disease at the other.

About two years ago a new element, radium, was discovered; today its effects on organic life are being widely investigated. Without a modern knowledge of physiologic chemistry certain avenues of biologic investigation are closed to us. And what great contributions to our knowledge and even our conduct of life may we not expect as a result of verified observations in the field of experimental work in inheritance?

These few illustrations may suffice to show that the closest touch with the many and diverse fields of biologic investigation is not only of value, but is an unquestioned necessity, if we are in any measure to keep pace with our intellectual opportunities. If there be any question as to whether research and graduate study be the essential method by which we are to come into our intellectual inheritance, let us ask what biologic conceptions have most affected our thinking of today; out of what data have those conceptions been formulated; and how have those data been revealed?

One of the conceptions most concerning us as teachers is that on which the so called genetic method of teaching is based, for it recognizes as a fundamental principle of psychology, that the child repeats in his own mental development, the development of his race. This is merely the application of the dictum—phylogeny is indicated by ontogeny, or, the history of the race is repeated in the individual— a conception based on the comparative anatomy and embryology of many types.

The method of research by which all great generalizations have been verified, is the laborious method of repeated observation, with here some observations affirmative to theory, and there, some observations contradictory to it. The final conclusions must take both series of observations into account, must be the mean of both. What better instrument for the training of the mind, for the tempering of the judgment, than the great storehouse of biologic processes and phenomena?

One of the greatest needs of the teaching profession is a high ideal of scholarship. Pedagogy seeks to put teacher and pupil in right relations with each other, but I sometimes think it neglects the very heart of the matter in paying as little attention as it does to the conditions under which the result aimed at is to be secured; for teachers are given little opportunity to be progressive and well informed and to nurture enthusiasms.

Probably nowhere in the curriculum of our educational system are such heavy demands made on the instructor as in the secondary schools; for while the demands for scholarship are high, the claims on the personality and on the time of the teacher are so great as to afford little opportunity for him to meet the higher scholastic requirements demanded of him; ultimately he becomes depleted both in mind and body.

The teacher needs some source of recovery and inspiration. It seems to me that teachers of biology might find this in the higher walks of their own calling; in research work, in some of the many fields open to them, for this is an avenue to far more than to mere scientific detail. So large a field as biology offers an exceptional opportunity for the choice of a recreative pursuit as well as many opportunities of association with those whose own achievements and insight inspire lagging strength. Without such association, the teacher inevitably suffers from too continuous intercourse with his inferiors in experience, and is in the gravest danger of losing sight of the true standards by which to measure his own worth.

From living too long with his nose too close to a grindstone, he loses perspective, and failing to see true values, fails to be able to impart them in his teaching. To be the best informed among the ill informed, is often a calamity. To be an appreciative student among students in any department of knowledge is a great and inspiring privilege.

Every intellectual man has an avocation as well as a vocation, and the real man is more often revealed by his avocation than by his vocation. I would suggest that the teacher of biology find his avocation in study and research in his own field. Then he will grow in knowledge as in his power to impart, and the older teacher will be the better teacher instead of being limited to what he can find in an old textbook, and tolerated only until he can be retired on a pension fund.

Teachers should be students, for the pupils' highest opportunities are determined by the teacher's limitations. Study and research keep the teacher in the attitude of a learner, and by so doing, keep him sympathetically in touch with the student attitude of his pupils.

Moreover, biology is essentially a subject of relations, the knowledge of the interrelation of the different fields of biologic science can be in no way so well appreciated as by striving to know some one subject exhaustively, and the whole subject as growing science. The presentation of biologic data in their relations is part of the very subject-matter of biology, without which it ceases to exist as a science, and becomes a mere exercise in observation. A student recently remarked to me, that he had learned more in two weeks from a celebrated surgeon in a hospital in Vienna, than in any year of previous study, because his professor taught anatomy in relation to embryology. The details of the subject as intellectual stock in trade lose their larger value out of relations, and can be presented in their true relations only by those who know their value in a larger scheme of knowledge.

I believe that every teacher who keeps his enthusiasm alive through years of professional work has, as the source of his inspiration, an intense belief in the value of the subject-matter he teaches; and it seems to me that the teachers of biology have exceptional opportunities of continued contact with the original sources of inspiration in research through study which may mean not only their own progress, but which may contribute in some small measure, however remotely, to the establishment of some great truth.

Teachers are the middlemen between closeted scholars and the busy world. The more they can bring of scholarship to their teaching, the more they can contribute towards the creation of an educated public. Knowledge is worthless if it be not used as an instrument to dispel ignorance, and, other things being equal, the best scholar is necessarily the best teacher, because he has more to impart. To one, the most useful form of biologic knowledge may mean economic questions of relationship; to another, familiarity with the forms about him; to some, physiology in its more utilitarian phases, or in its larger sense; while others may value some more purely scientific phase of the science such as evolution through variation, or the laws of heredity.

But whatever line of work we pursue, let us remember that the more helpful methods of teaching are the broader ones, those which open avenues of suggestion to the teacher and pupil alike. If we are teachers of students of more mature capacity, let us strive to be worthy leaders of a good cause. If our pupils are inappreciative through ignorance and immaturity, let us, while we try to illume their darkness, strive to hold to our own high standards for the preservation of our own intellectual lives, and resist with the whole force of body and mind, the depressing atmosphere of ignorance.

In conclusion, teachers are unworthy of their high calling who cease to grow in the field of knowledge in which they profess to be masters. They are unworthy as ideals for the young, whose best opportunities they represent, when they cease to be students.

It is to be deplored that the conditions under which secondary teachers have to work afford so little opportunity for the nurturing of the intellectual life, but it devolves all the more on the individual to wrest from importunate service a tithe of time in which to keep pace with progress. This can only be done by the biologist, through continued graduate study and research.

DEMONSTRATIONS

1 A method of mounting plants or animal tissues in glycerin jelly between strips of mica.

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2 A method of supporting developmental stages of seedlings or animals on a gelatin film supported by a plate of glass and preserved in 4% formalin and exhibited in an appropriate specimen jar.

BY J. E. KIRKWOOD, SYRACUSE UNIVERSITY

3 A few slides of reptiles' blood containing Haemaspondian parasites in the corpuscles, with an explanation of two stains adapted to such preparations, namely tolnidin blue and a stronger form of Moyer's haemalum.

BY C. W. HAHN, HIGH SCHOOL OF COMMERCE, NEW YORK CITY

Section C—EARTH SCIENCE

EARTH SCIENCE, HISTORY AND CULTURE

BY EUNICE E. PERINE, STATE NORMAL COLLEGE, ALBANY

The term earth science is one that has crept into our language within recent years. It is a word born of our necessity; one which has come to us with the growth and development of sciences themselves, and like the much maligned "fads and frills" of our modern education has, because of its intrinsic worth, become a citizen of all scientific literature. Earth science is a term at once broad enough and exclusive enough to define the realm of physiographic environment and natural phenomena with their organic and inorganic relations to each other. The popular idea of this subject embraces all facts that pertain to the earth, in their many changeful relationships, and from whatever kingdom they may be chosen. We stand bewildered with the magnitude of the subject. Its zenith reaches the farthest star and its nadir is the center of the earth. But when we turn to its scientific aspect law and order are restored. The word science is of all English words the most unassuming and restful; in its simplest interpretation it is "knowledge set in order." It pretends nothing that it has not, it only observes closely, thinks logically and then with infinite pains coordinates and arranges with the utmost care that truthfulness shall be its guiding star.

Of all the physical sciences which rest upon the observation of nature, geography, or earth science in its fundamental form, is the most ancient subject to be studied with a view of ranking and harmonizing facts. Sir William Wharton said that it is sometimes denied to geography the right to call herself a science, the objection being made upon the view that it is a subject that can be memorized and not easily studied on any systematic basis or reduced to principles which enable advance to be made by means of discovered laws. This is due to a misconception of both science and geography. A desire for exact data concerning the position, direction and distance of places from a known center for purposes of intercommunication must have been felt as soon as the segregation of people began. In 1100 B.C. the Phenicians are known to have formed rude maps and charts of the Mediterranean coast for the sake of their primitive navigation, but the secretive nature of these early Mediterranean navigators and the silly jealousies of the coastal tribes of this time has resulted in little of value to the world in the line of records or charts. However, their efforts caused this land-locked sea to become the nesting place of systematic geographic information. Even at this early date geography was by no means confined to this sailor phase of the subject. As the need was felt for other topographic knowledge, facts of climatic conditions were added to the general fund until the definition of geography best known to us as a "description of the earth's surface" came to be generally accepted and has reigned supreme from the time of Anaximander to that of Ritter and Guyot. But beginning with the works of these two eminent geographers many definitions of geography have been attempted, among which that of Prof. Charles MacMurray is the one most beloved in popular parlance; so that it has almost passed into a proverb that "geography is a study of the earth as the home of man." This ringing and somewhat cursory statement touches a vibrating chord in the pedagogical progress of instruction today, for it emphasizes the human element in much that is of highest worth of the education of humanity. As the "proper study of mankind is man" so an accurate and well correlated knowledge of one's environment presupposes the environed and can not afford to omit or underrate the value of the chief actor. But recently this definition has been severely criticized as being "a statement of the Ritterian view in the extremest form," on the ground that it excludes those interrelations of the different members of that environment with each other. "It is difficult" says Mr Charles R. Dryer in an able article printed recently in the *Teacher's Journal*, "to see what reason there is in the nature of things *why* the relation of the land to the sea and the air, and the air to the sea, or plants and animals to land, are not as much a part of geography as any other relations." And so they must always be considered by those who have best understood the interrelationship of the environed to the environment. Mr Gilman, in the *North American Review* says of Carl Ritter: "He regarded the world as an integer, an organized body, every part of which had an important relationship to every other part, and all these parts are essential to the completeness of the whole. In the complex arrangement of land and water, hill and valley, peninsula and highland, plateau and plain he saw no confusion but order, arrangement and adaptation to an end. The wind, water and land masses acting upon one another like animated organs, every region having its own function to perform thus promoting the well being of all the rest." Surely it is an extremely narrow, antiquated and most egotistic view to teach the youth of this 20th century that all the forces of the universe have no work to perform or functions to fulfil except as they are related to himself, rather than that he has his part to perform in the gigantic scheme of the harmony of creation. It is like the old Ptolemaic system of the revolution of the sun about the earth! It is because of these interrelationships that geography has been called the parent of earth sciences, of which the separate branches have grown to such proportions that each forms a treatise by itself. Thus the form and dimensions of the earth's surface are best treated in geodesy while geology, botany, zoology, archeology, meteorology and oceanography are other lusty children of the mother science. But it is to the parents of all these sciences that we must turn in taking a large and comprehensive view of the united results of knowledge gained through these various avenues; and it is the ability to master such a perspective presented by geography that is of most value to the pupils in the elementary and secondary schools. At best our teaching is too petty, too narrow in its horizons. It is the psychologic value of a subject that proves its greatest usefulness. The day is long passed when the training of the will, memory or imagination as so many separate faculties of the brain has had a place in the mind of any serious student of psychology. The doctrine of apperception teaches a better lesson than the need of so called "faculties" of the mind, and instructive material should no longer be chosen because it is good for the memory or imagination but because it follows the pupil's immediate interests and bears a vital relation to the future life culture of the individual. Only in this way is it possible to present a subject in accordance with psychologic principles, and then every native capacity will be given adequate exercise in an easy and a natural manner. To Herbart and the Herbartians belongs the discovery that the sole and paramount aim of the training of the youth is for citizenship in its broadest sense, and it was Colonel Parker who said that the object of education is "neither for knowledge or discipline but to gain citizenship through these."

But human geography is history and any treatise upon the history of geography forms an integral part in the history and development of the race. If the goal of education is the training of the individual for perfect citizenship, the dual purpose of man's existence must be kept in mind. Pope's adage that the "proper study of mankind is man" is not true of man as a unit, but as a collection of human beings. Some one has said that man as man is a Robinson Crusoe. Without opportunity for development in what Goethe so aptly calls the "stream of life," deprived of his franchise and robbed of his inalienable right to citizenship, the story of poor Crusoe is a record of petty personalities and although it is manly in its elemental struggles to conquer conditions and to preserve individuality, it is only a story because he had no civil self and did not belong to a state, and therefore lacked that essential quality which results in the climax of nationality. This biographic view of history has its proper place in the elementary and grammar grades. The child is in the "hero" age when the daring and dramatic deeds of an Alexander or a Washington appeal to his hero-loving nature, but the end of historical teaching is not attained if he is not taught to stand upon the mountain peaks and to view nations or races in their totality and to profit by the lessons they teach, each in its own peculiar environment, of contentment gained through control not alone of the opposing elements, but of control and adjustment of self to surroundings. The history of every nation is well defined along four definite lines. First, the struggle for bare existence, the plain and prosaic scramble to supply the positive necessities of life, food, shelter and clothing. This is the Robinson Crusoe fight for physical control. Second, that of passive contentment, or comfort. This is the stage in which the animal and physical control have been partially gained; fear of extinction is no longer a factor and the rise of mechanical arts and industries for the supply of wants begins. Third, that of active contentment or happiness, when science and literature, architecture and arts mark an epoch in the history of the race. Fourth, that of luxury. And this is at once the period of greatest peril and greatest opportunity in the history of any nation. If the individuals have not then learned, at least to some degree, that it is their duty and privilege to respond to the demands of environment, not in an egotistic and selfish sense, but as one very important yet humble factor in God's grand plan for the universe, there can be no harmony. The energy that formerly was used in subduing physical conditions must find its outlet in some direction, for energy in the human as well as in the physical world is power to do; and a misdirected effort of this energy leads to greed, sensuality, lust and crime, and is as certain to end in the disintegration of a nation as it is to determine the disgrace and destruction of an individual. On the other hand the right use of native energy at this crucial point in a nation's history is its golden opportunity for the culture of abilities and the nurture of talents. The record of the past offers many striking examples both from the shadows and the high lights of this picture. We do not need to be reminded that Rome in all her splendor dropped into luxury and decay or that England and America proudly hold the banner of purity and nobility of citizenship to be their chiefest aim.

The Eurasian continent when considered as a whole resolves itself into a rugged island structure with its two main continental mountain ranges, the more important extending with the greater length of the land mass, from the east to the west, and the other dividing it longitudinally. This vast island is fringed both upon the north and the south with a series of peninsulas extending boldly or timidly into the sea. Consider the position of this great land mass as a whole—stretching from the arid latitude of the arctic seas to the genial tropical conditions of the peninsular regions in the south, and that great rugged physical cross carved in relief upon its central and comparatively narrow land surface, and think how much of its history can be read from the map. Four distinct races have arisen here as a direct result of the geographic impossibility of passing natural barriers, each responding to its environment in an original fashion according to its ability to comprehend and conquer conditions; or, turning to Europe, of the three southern peninsulas Greece, because of her position, caught the first output of civilization from Asia and because of her own peculiar environment gave to the world the Hellenic race with all its wonderful genius for refinement and culture.

That a fundamental relation exists between earth science and history will not be disputed. It is not the purpose of this paper to discuss this question in all its minuteness, but to offer some few thoughts as to how this particular vital relationship can be made to serve the purpose of true culture in educational discipline. Geography can and does do much but it can not do all. Greece benefited greatly because of her geographic position, but that did not bring about her peculiar individuality. During the centuries that she lived her isolated land-locked and island-bound existence, surrounded by perfect climatic conditions, through her native love of perfection she fed and feasted and grew beautiful, not only because of her innate ability and willingness to respond to these conditions but because she deliberately set herself the task of learning how to respond. It has been said that neither the Greeks in any other country nor any other people in Greece could have been what the Greeks in Greece became. Blood and home make the man! Neither alone can perform its perfect work, for it is the conscious, intelligent and original response to environment that is necessary. Of all the countries of Europe Greece is that part of Europe most like the entire continent. It is Europe in miniature, with all its ragged coast line, peninsulas and islands, and most clearly typifies European civilization. Too far to the east to be kindled by the fiery zeal of exploration and colonization that so early affected the western outposts of the continent, Spain, Holland and Scandinavia, she lived her beautiful life in comparative peace, and the energy of this most European of all European countries was turned to that of producing the highest and best culture the world has ever known, that of making men "four cornered without defect." Italy has had the distinction of being the center of the world's political civilization but never the center of originality. This second southern peninsula presents a second necessary effort in European civilization. Rome subdued, dominated and organized through the indomitable strength of her impregnable position plus the iron energy of her personality, but to Greece belongs the genius of originality, and cultured minds of all ages have been her reverent disciples. Thus each nation finds its own key in which to vibrate in this harmony of history. Germany pulsates with the deep organ tones of her rugged simplicity and love of scientific truth, France thrills with the lighter, gayer activities of fashion and fancy, England throbs with the rich cathedral music of its Anglo-Saxon traditions, influences and possessions, while America is said to almost growl out her practical tones of Rooseveltian strenuousness. But each vibration has its work to perform and all are needed in the symphony of creation.

The culture epoch idea presents the thought that the child in its growth imitates the development of a race, each period of its advancement being clearly marked by its appeal to different interests until at last, like the groping nation in its struggles for existence, through a series of evolutionary steps finds itself in the larger and fuller realm of conscious personality. This self-finding is the very essence of culture and by culture is not intended the superficial meaning that is often applied to it in the popular and mistaken use of the word. Culture is neither an accumulation of facts, that reflect little credit on either the pupil or the instructor, nor an aping of the so called polish of the dilettante nor a wise marionettelike nodding over the obscure meanings of Browning, that only affirm an entirely false conception of the standards of living.

Plant culture is not the breaking of the seed into expressions of life—this is germination—but the careful nurture of the little individual in order that it shall be given every opportunity for self-development. Education does for the human mind what the soil, moisture, air and sunshine do for the seed, draws it out, causes it to unfold to the facts of life, but culture offers an opportunity and a method for self-discovery. John Addington Symonds declares culture to mean the "raising of previously educated intellectual faculties to their highest potency by the conscious effort of their possessors," that is, "self-effectuation" which is the highest end of culture. The word "faculties" as used here, so long a part of the nomenclature of the older psychology, still clings; but it is evident that the mind activity as a whole is expressed from his later use of the word "self-effectuations." This is certainly an expression of self as an individual, a unified whole and stands for character. A definition more in accord with the Herbartian idea would be, the adequate exercise of every native capacity in order to obtain the highest mental potency. Some of our deepest students of culture, Emerson, Arnold, Goethe, Shakspere, have all laid great stress upon the creative power of the mind. Matthew Arnold said that "the highest function of man is a free creative activity," and President Eliot speaks of this same ability both as a "constructive imagination," that power to create a whole from fragments or the perfect conception from bits of the perfect found in widely separated places; and the "receptive imagination which entertains and holds fast the visions genius creates or the analogies that nature suggests." These two functions of the mind have long been recognized in literature, poetry and art and as knowledge increases and better methods prevail, are becoming all important factors of scientific and historical teaching.

Geography offers from the beginning constant exercises in this direction. Maps and charts are but attempts to depict the real in an imaginary way; but if these symbols do not bring with them the strength and force of reality they are meaningless. Sand tables, field lessons and the problems of the laboratory have done much to vivify the work. Everywhere the increased excellence in methods of presentation is seen and felt in the vital growth of the pupil expressed in power to observe fully, describe with accuracy and to form correct inductions and deductions. This is an onward step, but it is not all that is comprised in the term "culture." The capacity for constructiveness as well as receptiveness is an inherent part of human nature. When we read history with a thrill of imagination or Shakespere "with the heart," or when we watch the squirrel gathering his winter supply or the "robins pairing and nesting in the trees," and learn the lessons thereby, we are so much nearer the true idea of culture which has always included quick perceptions and receptivities, broad sympathies and the keenest sensitiveness to the manifold relations of environment. It was once my good fortune to be one of a party that strolled with John Burroughs one lovely spring day over the mountain that led to the famous little "Slabsides" and I can never forget with what infinite tenderness he stooped to lift the drooping head of some little wood flower as he would have put his kindly hand gently under the chin of a very little child. The sympathy was very strong and very simple.

Culture is a process and must begin in infancy. The kindergarten is based upon these principles of self-discovery and self-control. Nowhere is the field broader or the opportunity greater than in the unfolding of this vital connection between earth science and history until through the disciplinary process of secondary and college training the youth is made to live in an atmosphere of the subject he is pursuing and to see individuals, continents, nations and races in their totality and to recognize himself as part of the whole. This makes for the truest culture and its outcome is the inalienable right of citizenship and the endowment of character.

REPORT OF COMMITTEE ON LABORATORY EXERCISES IN PHYSIOGRAPHY

The report of the committee on laboratory exercises in physiography was made the basis of a handbook published by the State Education Department. It contains directions for performing the laboratory exercises in physiography in the new syllabus and will be furnished without charge for the use of teachers and students in the laboratory.

FRANK L. BRYANT, Erasmus Hall High School, Brooklyn
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Committee

Section D—MATHEMATICS

THE NATURE OF APPLIED PROBLEMS IN ALGEBRA

BY DAVID EUGENE SMITH LL.D., PROFESSOR OF MATHEMATICS IN TEACHERS COLLEGE, COLUMBIA UNIVERSITY, NEW YORK

Two schools of mathematics

From a time so remote as to deserve being designated as immemorial there have been two distinct schools of mathematicians. The first in point of time and numbers, though not of influence, is the school of practical mathematicians, the men who made our commercial arithmetic, settled our methods of computing, furnished our genuine problems in mensuration and mechanics, and used the mathematics of the theorists as far as they had need for them. The second school is that of the theorists, the dreamers in the science and the mystery of numbers, the logicians who built up our geometry, and the men who have posed or ranked, and now rank or pose, as original investigators. The smaller minds in each school have always affected to look down upon the minds of the other, but the larger minds have sought rather to appreciate to the full the thoughts and labors and aspirations and results of the masters in both fields. So Thales, who in times remote founded the science of geometry, was one of those who did not scorn to use that science for practical ends, and Archimedes of ancient Syracuse, and Heron of Alexandria, and Newton, Laplace, Lagrange, Kelvin, and Klein, are among the multitude of those who are imbued with this me all-embracing spirit.

In our day we are not free from the old distinction, and the world will probably never break down the barrier. On the one side the inquiry will be raised, Cui bono? What is mathematics good for? What are the genuine applications? And on the other side the dogma of mental discipline will be sounded forth from the minarets of the city, and the faithful will be admonished that utility is the aim of inferior intellects.

Now two such schools of thought can not exist through the centuries without each having the support of truth. There is never any continuity founded upon falsehood. Hence it comes that the world's best teachers have always sought the truth in each of these schools. They have recognized the value of pure mathematics per se, but they have also recognized the value of the science as it measured up in one way or another the quantitative side of human life.

Let us see, for example, what has been done in our day for arithmetic, that we may estimate more clearly the possibilities for reform along the higher lines of algebra.

The question in relation to arithmetic

Now in arithmetic no considerable number of people seriously think of banishing the drill work with abstract numbers. The ability to work rapidly and accurately, developed by centering the thought on the operation itself and not on the interpretation of a problem, is considered vital. It is here that students are the most deficient when they enter college, and there is a just complaint in business that this phase of work is unduly neglected. On the other hand no one would think of having no concrete problems, in which the pupils should translate a question into the language of number and answer it in that language. The chief dispute of late has been as to the nature of these concrete problems. There are several possibilities for them:

1 They may be mere puzzles, with no reference to practical life. Such puzzles are not without their value. They often arouse an interest through their very absurdity, as in the 7 cats killing 7 rats in 7 minutes, or through their evident impracticability, as in the pipes filling the cistern. But no one would advocate more than a few such problems, and common sense would suggest scattering them so as to recognize their peculiar value of enlivening the game that is being played in a mathematical course.

2 They may be obsolete business problems as well as modern ones, on the principle that the reasoning involved is quite as good

with unreal as with real examples. This would, of course, be a sound enough argument if it were not for the fact that it is unnecessary to give false ideas of the business world about us. Since just as good reasoning can be obtained from genuine problems as from those that give a distorted idea of practical life, the latter become pernicious. Such are problems in equation of payments, partnership involving time, and alligation, all of which have been banished from modern arithmetics.

3 They may be genuine business problems gleaned from the world about us, types of what the child is to meet, examples with an interesting and valuable content, questions that relate to the country's resources, to the daily life of our people, to the interests of the living rather than of the dead. All modern writers on arithmetic seek such problems, and it is only a matter of patience to find them in large supply. Such problems are sometimes criticized, but these criticisms will not deter their growth and extensive use with all textbook makers and all modern teachers. They are here to stay.

The question in relation to algebra

Now how is it with our algebra? Are the conditions similar to those of arithmetic? Have we an inherited mass of problems as open to criticism as the conglomeration of arithmetical examples that have come down to us in considerable measure from the 15th century? In other words, are there types to be considered corresponding to those already mentioned in arithmetic?

1 What about the abstract work? It is not in the province of this paper to elaborate this topic. But briefly it may be asserted as probably not open to serious objection that there must be the same mechanical efficiency here as in arithmetic, and this better comes from manipulating a large number of abstract functions than from solving a smaller number of concrete problems. Facility, certainty, accuracy in this work are indispensable in all higher analysis and applied mathematics. This must, therefore, stand about as now, save that we might better the sequence, merely eliminating absurd concatenations that are never met, and substituting forms that are common in later work.

2 What shall be done with the puzzles? My hope is that they may be retained within reason, simply for the amusement and interest that attach to them. If their value in this line is recognized, they are not open to objection. No student considers very seriously roblem about finding a number which increased by a seventh of f equals 19 (historically the oldest problem involving a linear

equation that has come down to us). It is interesting, it furnishes some valuable exercise, and as a type it is unobjectionable if used in moderation.

3 But what is the outlook for genuine problems? Can we regenerate algebra as we have regenerated arithmetic? Is there a field in which algebra is really used, and which at the same time is one that the pupil is prepared to enter? Can we touch life with the equation, tell any of the story of humanity with the formula, and give to a function a genuine social content? If we can not vitalize algebra, would it not be better to reduce it in quantity, with the confession that its mere educational value does not warrant, and that advanced mathematics does not need, the expenditure of a year and a half of a pupil's time in the manipulation of abstract and seemingly useless functions?

Personally I am an optimist here as elsewhere. I believe that if we search out uses for algebra, aside from the uses of the subject in higher studies, we shall find them. While I am forced to admit that we do not have a large number now, I believe it is because we have hardly begun to look for them. Twenty years ago a genuine American problem in arithmetic was somewhat of a rarity; people said it was necessary to preserve the inheritances because we had nothing as good to substitute; but today, authors are finding plenty of genuine applications, and they find them simply because they look for them.

The possibilities for algebra

Now what are the possible fields for algebra? In the first place there is the formula, the most natural of all introductions to algebra. Instead of having a pupil begin by manipulating a lot of meaningless functions, it is perfectly feasible to let him see at least one use of algebra by beginning with genuine formulas. Happily the field is here a fertile one. The artisan's journals furnish many illustrations, the business rules of arithmetic furnish others, and elementary science supplies still more. Opposed as I am to turning our classes in mathematics into classes in physics, I am still aware that every child entering the high school knows enough of natural laws to appreciate formulas on the lever and on uniform motion. Formulas embodying the most common cases in general percentage, in interest, and in discount are not only easily understood by children, but they illustrate one of the chief uses of the algebra of which they are beginning the study. Hence there is abundant material of this kind for the first steps in the new science, material that is interesting, that is valuable, that is related to human life, and that is practical for the artisan, the merchant and the business man generally. Once the interest in such formulas is aroused, this interest will help to hold the pupil to his work in the fundamental operations with abstract functions. But I am not without hope that even in the latter field a line of applications will be found, just as we find this line in arithmetic on the one hand and calculus on the other.

The next field of applications that has proved fertile thus far is related to the negative number. Instead of approaching this subject from the abstract side, or with the help of the single illustration of debt and credit, we now have abundant material of which the teacher can take advantage. Chronology, latitude, longitude, temperature, assets, games, the numbering of east and west streets, opposed forces, and many other similar lines of practical applications make the negative number seem as real and as usable today as is the positive.

The linear equation with one unknown also offers abundant practical material. One has only to seek and he finds. Percentage problems are particularly valuable in showing the practical uses of the linear equations, although the field is by no means limited to this group of applications. I should therefore look with suspicion on any algebra which should appear today without a considerable number of honest business problems under this head, problems that are interesting, valuable, informative, and as full of mental discipline as the old inheritances that have come down to us through the middle ages.

In the study of ratios, with those particular subtopics known as proportion and variation, we have an abundance of applications that are of the best type of excellence; problems with a genuine content, but not involving technicalities beyond the understanding of the pupil.

When we come to linear equations with two unknowns, however, we are not so fortunate, and if we increase the number of unknowns to three or more we have practically no good applications in any of our books. As a result we find ourselves resorting to the mere puzzle, to some absurd hypothetic case (which is the same thing), or to some unreal concrete question. To be sure we can clothe the problem in concrete language, as in finding the temperature at which the number of degrees Fahrenheit is five times the number centigrade, but such problems do not seem genuine, and really are not so. About the best class of problems of this kind at present available is that relating to the mixing of metals or of solutions, but the field is soon exhausted.

In the matter of quadratics we are still more troubled to find genuine applications. Physical questions, like the well known problem of the point of equal illumination of two lights and certain problems relating to moving bodies, help us a little. They usually fail, however, because they involve technicalities beyond the knowledge of the pupil. We therefore find ourselves today with practically no good applications in quadratics.

I have now laid before you the general issue. Let me recapitulate.

1 If we can secure genuine, vital problems of the day, to illustrate the various chapters of algebra, we shall gain in the interest, and we shall at the same time enhance the practical value of the subject without detracting from the educational value. This has been done in arithmetic, and it may be hoped for in algebra.

2 In certain lines we can find plenty of practical problems, although textbook makers have not as yet availed themselves of this material. These lines are notably the study of the formula, probably the most practical part of all algebra, and the linear equation with one unknown which ranks a close second in the matter of usableness. To these may be added the negative number, and the graph which is so closely connected with it. The algebraic graph, however, is not of so great practical importance as is generally assumed. There may also be added the study of ratio in its largest sense, and the complex number.

3 In the work in simultaneous equations and in quadratics we have brought together only a very small number of good practical applications. It is, therefore, to this field of work that I invite your particular attention. I do not believe that we should give up the matter and say, "It is hopeless," "There are no such applications," "What is the use of bothering with the matter so long as the examining bodies remain asleep to the issue?" Just as some of our best teachers have discovered of late a wide range of practical and easily understood formulas, notably in artisans' journals and handbooks; just as the number of illustrations of what was once so puzzling, the negative number, have been discovered; just as the linear equation has of late come to be used extensively in throwing light upon many involved problems of arithmetic, so I have faith that we shall yet find genuine applications for our simultaneous equations and quadratics. It is worth much for us to get together like this and face the issue. It is helpful to clear the atmosphere and see where we stand. We can never solve a problem until we know what it is, and if you and I know the goal we may, at least by our sympathy, assist others in attaining it.

I know very well that this suggestion will stimulate some to be on the lookout for genuine applications, that it will have an almost equal value of making a larger number sympathetic with educational advance, but that it will be entirely misunderstood by a small minority. For if it be said that this is an appeal for utilitarian mathematics as against cultural, I have lamentably failed in presenting my case. My appeal here, as in arithmetic, is simply this: Let us cast away pretense and sham in our applied problems; let us have them stand on their merits as puzzles, like the number guessing, as interesting inheritances like the cistern pipes and the couriers, or as real and usable applications taken from the commercial, the scientific, or the social life of today. Let us neglect no necessary abstract work; let us drill upon processes until they become mechanical; but let us make the subject more interesting by honest applications, more valuable by a study of real conditions, more inspiring by furnishing a key to new chambers in the quantitative structure through which we pass. Above all, let us not despair of doing all this, rather taking hope at the success in already finding applications not thought of only a few years ago, and stimulating by our sympathetic interest all who are laboring with honest purpose to improve our algebraic teaching, to rejuvenate this the third oldest of the mathematical sciences, and to make attractive a subject which has of late become rather the most gloomy of the antechambers through which the student passes to reach the vital, progressive, pure mathematics that lies beyond.

THE PURPOSE AND METHOD OF THE STUDY OF ALGEBRA IN OUR SECONDARY SCHOOLS

BY E. P. SISSON, COLGATE ACADEMY, HAMILTON

By secondary schools I mean the high schools and academies. The purpose of the study of algebra is twofold: (1) disciplinary, (2) practical.

1 The development or training of the mind in regular and systematic action is discipline, therefore the logical faculties are emphasized. Much attention is given to answering the "why," for each step in the process.

2 The practical emphasizes the results, and therefore calls attention primarily to the "how." The answer is the first consideration in the student's mind.

I presume no teacher of algebra keeps but one of these purposes in mind, but rather his thought is upon which purpose shall the emphasis be given.

From my observation algebra is the most poorly taught of all mathematical subjects in our secondary schools; arithmetic next and plane geometry the best.

No one of these three subjects is so logically developed and taught as plane geometry. There is no reason why algebra and arithmetic can not be presented in just as systematic and logical order, to our pupils, as plane geometry.

In our arithmetics we find definitions, rules, examples and in most cases answers to the examples, and a few examples solved by way of illustration. Most of our algebra texts are made up the same way, with this exception, that the tendency is to omit the answers to the examples in the algebraic texts. I would like to see every rule and answer omitted from all textbooks in arithmetic and algebra, also all model solutions of examples, and thus give the student an opportunity to think and do for himself; and I imagine that some of our teachers would have an opportunity to do more independent work as well, which would not be a bad thing.

The method of presenting a subject depends to a large degree upon the purpose. The method is also dependent upon the age and advancement of the pupils.

All conditions should be carefully studied and taken into account before a teacher decides in detail upon the method he or she adopts in presenting a subject to a class.

It is my firm belief, after many years of experience in teaching arithmetic and algebra, that the method that emphasizes the disciplinary purpose in education gives far the best results in making our boys and girls strong, independent and logical thinkers, thus training them for leaders instead of mere machines and walking encyclopedias. Knowledge is not intellectual power.

The tendency today of our methods in our secondary schools is a smattering of many subjects : knowing a little about many things but a master of none.

In my opinion the best results are obtained by teaching algebra as a logical subject and developing the subject with the same degree of careful reasoning as in plane geometry.

The order of each general topic in algebra may be presented in a general way as follows: (This I give by way of illustration.)

1 Define the mathematical terms used only in the topic under consideration.

2 State the corollaries that are derived from the definitions given.

3 State the axioms used.

4 The propositions, which will include the theorems and the problems, and their demonstrations.

5 The corollaries that are established in the demonstrations of the propositions.

6 The application of the propositions demonstrated, which is the solving of the examples.

Division

I will illustrate my meaning by the topic of division, treating the topic broadly so as to include the forms of division called fractions and ratio.

1 Definitions

Dividend, divisor, quotient, division, reciprocal, fractional term, integral term, integral expression, fractional expression, mixed expression, rational expression, degree of term, degree of an expression

2 Corollaries from the above definitions

a The product of the divisor and quotient is the dividend.

b If the dividend and divisor are the same expression the quotient is positive one.

3 Axiom

a Dividing any expression by positive one does not change the expression.

4 Propositions

a Dividing by a number is equivalent to multiplying by its reciprocal.

b The quotient is the same in whatever order the factors of the divisor are multiplied.

c The quotient is the same in whatever manner the factors of the divisor are grouped.

d If the dividend is positive the quality of the quotient is the same as that of the divisor; if negative, the quality of the quotient is opposite to that of the divisor.

e The product of two or more quotients (or fractions) is equal to the product of the dividends divided by the product of their divisors and conversely.

f The quotient of the mth power of any base divided by its nth power equals the (m–nth) power of that base, when m is equal to or greater than n.

g Any base with zero as an exponent is equal to plus one.

h The quotient of one expression divided by another equals the sum of the quotients obtained by dividing the parts of the first expression by the second.

i Multiplying or dividing both the dividend and the divisor by the same number does not change the value of the quotient or fraction.

j The reciprocal of a fraction is equal to the fraction inverted.

5 Problems

a To divide any number by a fraction, multiply the number by the fraction inverted.

b To multiply a fraction by any number, multiply the dividend, or divide the divisor by that number.

c To divide a fraction by any number, divide the dividend, or multiply the divisor, by that number.

I will illustrate what I mean by the demonstration of a proposition by the following:

The product of two or more quotients is equal to the product of their dividends divided by the product of their divisors and conversely.

Translation of the above in algebraic symbols,

1 $c/n \times a/b = ca/nb$

2 $ca/nb = c/n \times a/b$

Demonstration

1 Hypothesis: The product of two or more quotients or $c/n \times a/b$

2 Conclusion: Is equal to the product of their dividends divided by the product of their divisors, or ca/nb

3 $c/n \times n = c$

Corollary: The product of the quotient and divisor is equal to the dividend.

4 $a/b \times b = a$

Same authority as step (3)

5 $c/n \times a/b \times nb = ca$

Corollary: If two identical expressions be multiplied by two other identical expressions the products are identical.

6 $nb = nb$

Corollary: Every expression is identical to itself.

7 $c/n \times a/b \times nb/nb = ca/nb$

Corollary: If two identical expressions be divided by two other identical expressions their quotients are identical.

8 $c/n \times a/b \times 1 = ca/nb$

Corollary: If dividend and divisor are the same expression the quotient is positive one.

9 $c/n \times a/b = ca/nb$

Axiom: Multiplying or dividing by plus one does not change the expression.

10 $ca/nb = c/n \times a/b$

Axiom: If an identity is true its converse is true.

The pupil must have a clear and accurate understanding of the terms: proposition, theorem, corollary, converse of a proposition, demonstration.

The pupil must see and comprehend that a demonstration is made up of a series of mental steps, beginning with the hypothesis and ending with the conclusion, and that each step consists of two parts: 1) The statement of a fact. 2) The authority for the statement, which is always found before the proposition demonstrated and never after the proposition.

I am of the opinion that there is not enough attention given to the definitions of the terms used. The pupil should both commit and clearly understand every definition under each topic.

Each topic I would treat in the same general order, and have every proposition rigidly demonstrated as shown above.

Those teaching algebra in the first class in our high schools could not carry out this method with the same degree of logical severity. Still the method in general need differ only in degree. I mean by this, have the pupils learn the definitions, corollaries, axioms and propositions, but let the teacher present the demonstration of the propositions very carefully, so the pupils will see and comprehend that there *is a reason* for every step taken in the process.

From my point of view algebra should never be taught sooner than in the third year of the high school course, and even then cover a less number of topics than is called for by some of our colleges of today. Quality and not quantity gives mental discipline. The methods used today in teaching algebra in many schools emphasize quantity to the expense of quality and thus encourage shallow and loose thinking.

The world today is calling loudly for deep, accurate and logical thinkers and not simply for breadwinners.

GRAPHIC METHODS IN ELEMENTARY ALGEBRA

BY WILLIAM BETZ, EAST HIGH SCHOOL, ROCHESTER

All human thought moves in three great spheres, namely, Nature, Man, God. It would be a profitable task to study the history of education with reference to the relative predominance of one or another of these interests. The monastic schools of the Middle Ages laid their greatest stress on religious training. With the "revival of learning" came a period of humanistic studies. The 19th century brought a marvelous development of natural science and of mathematics. Nature study in its widest sense is beginning to receive a due amount of attention and our school curricula are becoming more harmonious.

The method of investigation in natural science work is inductive. The actual conditions under which natural phenomena take place are reproduced in the laboratories, and experiments are performed. These must be repeated a sufficient number of times to warrant the derivation and enunciation of a law. Thus, every laboratory experiment is a question addressed to nature, and the result of the experiment is nature's answer. When the investigation is of a quantitative character, results are expressed numerically. In the simplest cases the experiment involves one independent and one dependent variable. The problem is to find a constant relation between them. Two sets of figures are finally obtained. One represents the successive values of the independent variable; the other, of the dependent variable. Now, it is evidently the desire of every investigator to communicate his results to others in the most lucid and compact form. The numerical or statistical method alone, it was found, did not accomplish this. Who has not heard of dry statistics? The solution was eventually discovered in the drawing of diagrams or graphs, usually in accordance with a system perfected nearly three centuries ago by a French mathematician and philosopher.

This is another instance of the practical utilization of a tool devised at first for purely theoretic purposes. When Descartes, in 1637, published his *Geometry*, he probably did not realize the possibilities of his system. His genius presided at the marriage ceremonies of algebra and geometry, producing a union that was to revolutionize science. Lagrange, in his fifth lecture on elementary mathematics, says:

> As long as algebra and geometry traveled separate paths their advance was slow and their applications limited. But when these two sciences joined company, they drew from each other fresh vitality, and thenceforward marched on at a rapid pace toward perfection. It is to Descartes that we owe the application of algebra to geometry,—an application which has furnished the key to the greatest discoveries in all branches of mathematics.

The fundamental idea of the graph as usually drawn is so simple that a child can comprehend it. If two lines (axes) intersect at right angles, any point in the plane determined by the lines can be located if we know its distances and directions from the lines. With the usual convention of signs, two numbers are necessary and sufficient to fix a point in this plane. An infinite number of points can be so "plotted." If the points be determined in accordance with some definite law, a configuration of points of definite geometric form is obtained. If the law is expressed algebraically, this configuration is a picture or graph of the algebraic form or function. A graph, then, is really a pictorial representation, a condensed record, of related sets of numerical facts. One set of facts is represented on one axis, the horizontal, the second on the other axis, the vertical. Points between the axes will show precisely which facts are related. If, for instance, equal divisions are laid off on the horizontal axis to represent units of time, and equal divisions on the vertical axis represent units of temperature, any point in the plane of the axes will show that at a certain time there prevailed a certain temperature. The line joining a number of these points for consecutive units of time gives a record of the temperatures during the interval of time considered—it is the thermograph for that period of time.

Frequently several sets of facts are closely related. It may be important, for instance, to know what influence the price of food has on wages, how tariff affects wages and how agricultural prosperity reacts on the amount of exports and imports, etc. It is only necessary to draw, on the same axes, the graphs of the wages, the food prices, the tariff rates, of the harvest results, for the same period of time, to derive valuable conclusions as to the interrelation of these facts.

Evidently the range of application of the graphic method is as wide as that of dependent phenomena, i. e. it is inexhaustible. This gives to the graphic method a great educational value. A recent writer says that the present mathematical renaissance has "a triune watchword—graphics, correlation, laboratory." Whatever criticism may have been directed against correlation and laboratory methods in mathematics, graphic methods are now indorsed by all progressive teachers. An algebra text is incomplete without them.

When and how shall this graphic work be introduced into elementary algebra? Graphs can be used to advantage at almost any stage of the high school curriculum, and therefore graphic work should begin as early as possible during the first year of the high school course. No special preparation for it on the part of the pupil is required. But before the specifically algebraic applications of the graph are taken up, the learner should be given a certain amount of introductory work impressing upon him the value and beauty of this method. I have found the following sequence of topics convenient.

1 Weather data (thermograph, barograph etc.)
2 Science data
3 Statistical data, relating to

- *a* Population (increase, nationality etc.)
- *b* Natural products (agriculture, mining)
- *c* Municipal, state and federal administration (taxation, postal service)
- *d* Exports and imports
- *e* Industries (amount of manufactures, scale of prices)
- *f* Commerce, interest, stocks and bonds, insurance
- *g* Economics (wages, strikes, prices of food, hours of labor, etc.)
- *h* Hygienic conditions (mortality, diseases)
- *i* Religious and educational conditions (school and church attendance, cost of maintaining schools, churches etc.)

4 Geometric applications

5 Algebraic applications
- *a* Solution of simple problems (preferably motion problems)
- *b* Simple functions (ax + b)
- *c* Linear equations (ax + by = c)
  Rule of intercepts and quadrants
- *d* Simultaneous linear equations
- *e* Simple quadratic equations (circle, ellipse, parabola, hyperbola)

No one class should attempt all the preliminary topics. A few words of explanation may be necessary. I believe that the thermograph constitutes the easiest approach to the subject. The predecessors of Descartes plotted figures by rectangular coordinates called latitudes and longitudes. I would follow their example only to the extent of keeping the work, at the beginning of the course, in the first quadrant. Accurate weather data may be obtained from any weather bureau. The official report blanks contain the hourly readings and the averages for days and months. After an introductory lesson explaining the meaning and use of squared paper, the pupils bring a "daily thermograph." Then follow thermographs of the daily averages of one month, and of the averages of the same month during the last 20 years. (For a description of similar work see *School Science and Mathematics*, May 1905.)

Science data developed in the laboratories of the school will be gladly furnished by the science teachers. Simple experiments, such as the weighing of pieces of crayon, might be performed before the class.

The statistical work may be based on newspaper and almanac records, on the reports of the various government bureaus, etc.

Valuable information is contained in the bulletins of the Census Bureau, or of the Department of Commerce and Labor. The class should be shown some representative diagrams, and should then be permitted to plot any data of special interest to them. Sometimes graphs of startling originality result. The pupils enjoy this work.

A simple transition from the first to the other quadrants is furnished by the geometric applications. The law of signs is readily comprehended. Geometric figures are plotted from the coordinates of their vertexes. The more important area formulas are deduced. How far this work may be carried, even in the grades, Mr Campbell has shown in his admirable book on observational geometry.

Motion problems furnish the best preparation for the algebraic work proper. The latter is presented so ably in the recent texts and in a number of monographs, that it would be a waste of time to consider it here.

Graphic work need not consume much time. After one or two lessons, a few minutes at a time will be found sufficient. *The main thing is that the graph become real to the pupil.* Every genuine graph tells a story. Professor Perry, in this connection, writes:

> I was once sitting on a committee when a manager was detailing reasons why attendance at certain classes was steadily dropping. In idleness I manufactured some squared paper, quite roughly, and plotted the numbers, and it became at once evident that some curious event had happened at a particular date which had produced the mischief. This led at once to a rectification of the evil. Now I do not say that a man clever at figures would not have discovered this from the figures themselves, but the importance of the squared paper method of working is that no worry over details of figures distracts one from the general story told by them.

If it be necessary at all to furnish reasons for the introduction of the graphic method, I should give these:

1 The graphic method brings the sum total of a set of related facts before us in a concrete, compact form.

2 The study of a graph may lead to the discovery of the law governing the facts it represents.

3 The graph furnishes an easy mode of interpolating.

In the school,

4 The graph represents the simplest means of correlating the mathematical and physical sciences, and of introducing the activities of genuine laboratory work.

5 It enables the student to test, at an earlier period, geometrical truths, and familiarizes him with the use of instruments and with units of measure.
6 It gives him a new tool for the solution of certain problems.
7 It makes him a more intelligent and interested observer of social, commercial and economic phenomena.
8 Last, not least, it makes the study of equations, individual and simultaneous, of the number system of algebra, intensely real, and affords a pleasant relief from the usual routine of that subject.

Let us rejoice, then, that the graph has at last come into elementary algebra. It has come to stay.

The paper was fully illustrated by blackboard diagrams, printed charts, and samples of work done by pupils. The following references may be of service:

1 The recent textbooks
2 Graphic Algebra for Secondary Schools, by H. B. Newson. Ginn & Co. 10c
3 Practical Mathematics, by Prof. Perry. Eyre & Spottiswoode, London
4 Discussion on the Teaching of Mathematics, British Association, 1902. Macmillan
5 Especially, Report of the Committee on the Correlation of Mathematics and Physics in Secondary Schools, of the Central Association of Science and Mathematics Teachers. 25c. Apply to E. Marsh Williams, treasurer, 52 South Kensington Avenue, La Grange, Ill.
6 Graphs, by Robert J. Aley. Heath & Co. 10c
7 *See also* School Mathematics, March 1904

GENERAL SESSION

Thursday afternoon, December 28

In recognition of the completion of 10 years of work by this association the following papers give some review of the progress and an outlook for the future of each section.

Section A—PHYSICS AND CHEMISTRY

BY WILLIAM HALLOCK, COLUMBIA UNIVERSITY

As the mountain climber from time to time stops and surveys the landscape, taking his bearings to get a clearer idea of how high he has ascended, what he has accomplished, of the paths that he has traveled, and lay out his future course, so for us in climbing the hill of knowledge it is desirable to stop occasionally and convince ourselves that we really have accomplished considerable and that we should go forward with good courage toward the accomplishment of much more. As we look back upon the development of the New York State Science Teachers Association and upon the place which the study of physics has won for itself in the past 10 years, I believe that we have every reason for gratification, every reason to look forward with good courage to the accomplishment of still better results in the future. It is not for me to point out the wonderful progress of the Science Teachers Association as a whole; that fact stands clearly established, and we are already the envy of other states that are longing for a similar organization of their workers in the same fields.

If we confine our attention more particularly to the development of physics in this period we can refer to the place which it has won in fields of education in general, relying with perfect assurance upon the fact that this association has contributed very largely toward the organization and systematic development of the subject in other states as well as in our own. Let us consider for a moment the situation of the study of physics 10 years ago. It had scarcely been recognized as one worthy of very serious consideration. One or two colleges had agreed to accept it as an entrance subject, and this, however, was in most cases very unsatisfactory, and in many cases the college continued to teach the subject as if the candidate who offered physics for admission had no knowledge of the subject whatever. In most cases the so called requirement in physics was a requirement from textbook work that could readily be crammed in a few weeks and was unsatisfactory from every point of view. A few devoted spirits believed that physics should be taught in the high school, and that it could be taught there, and if taught, should be taught by properly trained teachers. These few put their hands to the plow and today can look back with satisfaction upon the results which they have accomplished. In this connection it must be remembered that physics played the part of the point of the entering wedge and it was necessary for us to bring in not only ourselves but to drag along with us the other experimental sciences because our adversaries recognized that as soon as the first experimental science was admitted then no seriously valid arguments could be brought forward against the others.

We are often told that we have not lived up to our promises; that the study of physics is not as attractive to the student and is not as valuable for training as we promised it should be. That is only partly true, partly because some enthusiasts promised too much, and chiefly, however, because we have only commenced the development of this study and have had not a really fair chance to develop it as it should be developed. We remember that in the latter part of the 15th century when it was proposed to introduce the study of Greek into the schools and colleges or universities of the time, exactly the same hue and cry was raised as has now been raised against physics. The advocates of Greek were told that as a business proposition it might be desirable to learn Greek in order to deal with Greek merchants, but that as a matter of culture and education it was absolutely useless. Practically all arguments that have been brought forward against the introduction of science as being of economic but not of educational value were brought to bear against the study of Greek, and it was at least a century before it could be fairly said that the study of Greek was recognized in the European universities as of anything like the same educational value as the study of Latin. In one tenth of that time we have made very good progress toward convincing the educators that the exact experimental sciences have perfectly defined educational value different entirely from the study of the classics but qualified to develop a property of the human mind no less important and no less desirable.

We are told that there are less students in proportion electing physics now than there were 8 or 10 years ago. That may be the case. If so, two perfectly sufficient causes are apparent. In the first place when the courses were first established the desire for novelty necessarily attracted a large number, and many students elected physics simply because they thought that it was something new, something different, and certainly could not be any more difficult than Latin or Greek. It has been the experience of institutions as well as of departments that novelty brought in at first a large number whose presence was not an unalloyed blessing. Our own experience with the summer school at Columbia University is a good example in this respect. In the first year we had a very large registration of students who were habitual wanderers who went to every new school that was opened, not that any believed that the school was better than other schools but simply that it was something new and they wished to try it. Every year since that, the number of this class of students has fortunately decreased. This same thing is true of the study of physics. At first, under the influence of the glowing accounts of the beautiful experiments that were to be performed and the highly useful knowledge that was to be attained, many students were induced to elect physics without any real knowledge of why they were doing it. Gradually this class of students was eliminated from the course and only those came in who really had a desire to study the subject. The second cause for the falling off in the election of physics is one which really reflects the highest credit upon the nature of the course.

At first these courses were largely spectacular, not representing any real serious work, intended rather to amuse and interest the pupil than to instruct him in any fundamental principles or methods. In every case where the courses have been made more severe, more systematic, they have necessarily become less attractive to the student who is hunting for the easy courses, and it seems that the more of these undesirable students that can be eliminated from the study of physics, the better. There can be no more fallacious method of computing the success of a course than by the number of students who elect it. Most any college which has elective courses realizes that certain courses are elected because they are easy and certain others are scrupulously avoided because it is known that they are hard and success in them represents serious work. To me it is inexplicable how a great authority on education can find fault with the teaching of physics because it is made systematic and rigorous. Nevertheless, we are told by high authority that we ought not to require our students to do extensive drudgery in physics, we ought to amuse them with attractive and spectacular experiments qualified to distract them from the drudgery of the rest of their school course, that we ought to teach them the dynamo and the wireless telegraph and not bother them with the Ohm's law and the Wheatstone bridge. They expect us to make our study attractive, interesting, free from drudgery, and in the next breath they accuse us of not developing methods and habits of serious thought in the student. If I may be permitted to ask the parallel question it would be something like this: Why is the student of Latin compelled to spend two years on Latin grammar and Latin construction and the utterly uninteresting prose which is doled out to him in those early weeks and months of his course? Why is he put through this drudgery instead of being amused with the translation which somebody else may make of the *Aeneid* or of the poems of Horace? Why the drudgery of Greek grammar and not the delicious narrations of Homer? And yet the analogy is fairly complete for the high school student who is shown the wonders of wireless telegraphy before the fundamental principles of electricity; he will be absolutely incapable of understanding the situation, any more than the boy who reads a poetic translation of the *Odyssey* will be able to appreciate the beauties of the Greek language. No one seems to think it necessary that Latin grammar or Greek grammar or geometry or algebra should be made particularly attractive to the student. They are simply told that these things must be learned, and that they may like them or not, it makes no difference. For my part it seems to me that the very argument that the courses in physics are less attractive than they were is the best proof that these courses are becoming more nearly what they should be.

This is apparent, too, if we consider for a moment the attitude of the average college of today toward the courses in physics as given in the better grade of high school. We see that now the college feels justified in accepting the offer in physics as really meaning something and that it can start with that as a basis and go on without the necessity of repeating the course. Nevertheless, we must not allow ourselves to think that the physics in the high school is important only as a preparation for college. It must be clearly remembered that so long as but a small percentage of the high school scholars actually go to college, so long must the high school course be considered primarily as a finishing up of the education of the scholar rather than as the preparation of the scholar to continue his education at some other institution. For this reason above all others it seems to me that the courses in experimental science are of fundamental importance and must be taken with extreme seriousness. It is apparent that such is the case from the fact that we have today a decided movement in favor of a second year of physics in the high school, on the one hand, with opportunity for more serious work on the part of the scholar, and on the other hand, that there is a very strong movement for the introduction of the simpler and more fundamental principles of the science in the grades of the grammar school along with the study of the phenomena associated with plant and animal life. It is impossible to consider for a moment the present questions which are interesting teachers of physics without being struck at the enormous change in the situation in the last 10 years.

There is one other point in which the study of physics in the secondary schools has rendered a service to the cause of education at large which is of inestimable value. This service is in demonstrating the necessity of having a trained teacher to teach the subject not from purely theoretic points of view but from having an actual working knowledge of the subject. It used to be considered that any college graduate was necessarily a good school teacher. Nothing has done more to break down this idea than the inability of those men to teach the experimental sciences in any certain way, and the necessity for a specialist for physics and chemistry has demonstrated to more school boards the necessity for specialists in other lines than any other one thing.

Thus it would seem that at the end of our first decade we have every reason for being satisfied with the work of the association at large and of the section of physics in particular. We have only to press on in the same spirit and we may rest assured that our successes will continue. The line of progress has been fairly well laid down and we only need to run over the list of names of those who are actively interested in the development of the study of physics in the secondary schools in order to be perfectly sure that the progress will be unbroken and considerable. These men are primarily acquainted with the science of physics. They are also teachers. They are neither great investigators whose heads are in the clouds far above the average student, nor are they people who have been manufactured into teachers by a certain number of courses on psychology and pedagogy. They are people who know the subject-matter and the condition of the average pupil, and under these circumstances the teaching will come as a natural and necessary consequent. Let us then go on in the happy assurance that if we continue to work putting our best efforts into the common cause as heretofore, when after another 10 years we meet to balance our accounts again we shall have renewed cause for congratulation and hope.

Section B—BIOLOGY

BY A. D. MORRILL, HAMILTON COLLEGE, CLINTON

Huxley's *Practical Biology* published in 1875 revolutionized the study of natural science among English-speaking people.

This pioneer of laboratory science, emphasizing the work of the pupil and following the lines of evolution, was introduced into the college work of this country nearly 30 years ago, although many of the smaller colleges, secure in their conservatism, yielded very slowly, vainly hoping that the onward march of education would be reversed, placing them again in the lead. Today it would be almost impossible to find a college which refuses to teach the biologic sciences, in some form.

Long before the beginning of the past decade enthusiastic and well trained men began to teach biology in the larger high schools of the great cities. The struggle for recognition, adequate time and equipment has been a hard one, but now not only the larger cities but many towns have fairly equipped laboratories.

At first the unmodified type method was used in the high school, but it soon became evident to progressive teachers that changes must be made to better adapt it to the needs of the pupils, their age and mental development. This was done generally by lessening the amount of dissection or morphology and increasing the study of living plants and animals and physiologic experiments.

The laboratory work is the most critical part of science teaching, as the habits formed are fully as important as the facts gained. It is here that the student is made or ruined.

Laboratory guides are numerous, as many teachers have tried to meet the needs of their own classes and in an evil hour have been persuaded to publish.

There are two general methods followed, either that of making statements to be verified by the pupil or by the use of questions to lead the pupil to find things for himself; and there is a third which is a combination of both.

Personally I have found that the simplest as well as the smallest number of directions, within limits, give the best results. Even these are not distributed until the pupil has had time to examine his specimen pretty fully.

At first, with the living specimen, the only question I ask is what can it do and how. It encourages the pupil and develops his self-reliance to find on consulting his directions and later the reference books that he has independently discovered many of the facts which he is expected to observe.

The recitation becomes a conference, no two pupils having made exactly the same observations. Each pupil notes the points to be confirmed by later observation. Then the reference books give additional facts for verification or proof.

One difficulty with many laboratory guides is in their completeness. The pupil is often nearly helpless when thrown on his own resources by being confronted with a new form and no guide to tell or suggest what he should do.

With large classes a great part of the laboratory work must fall into the hands of assistants who need the most careful training that they all bring out the same important facts and that they do not yield to the importunity of the pupils, who find it easier to ask questions than to make their own observations.

The instructor should always be ready to answer legitimate questions or make suggestions which will enable the earnest pupil to find his own answers, but to the careless, thoughtless questioner he must be a tonic and stimulus to lead him to want to study his specimen for himself.

In the country it is possible to arrange field excursions without difficulty but in the large cities it is a much more serious problem. To make the field work of the greatest value the instructor should know the main things that can be observed on a particular trip, and by assigning topics or questions help the pupil to do definite and careful work which should be reported later. The material collected can be studied in the laboratory and specimens preserved for later use.

It is possible to make many observations on living plants and animals in the laboratory by the use of aquariums, vivariums, the Fielde ant nest, observation beehives and Wardian cases or conservatories.

In the high school course the earlier, disconnected observations in nature courses on plants and animals may be welded into a consistent whole and with the aid of further observations, comparisons, dissections, demonstrations and experiments on plants and animals an intelligent outlook on life may be obtained and a more perfect understanding of the human body than has ever before been possible.

The school garden not only helps the city child to come closer to nature and to understand the processes of agriculture but also gives a valuable mental training which will help in later biologic work.

It is hoped that this work on the soil may tend to develop a migration to the country. In the country the place of the school garden is fully as important although it must be managed somewhat differently. The effect of nitrifing bacteria on clover, the action of fungicides on the plants of the farm and the study and destruction of injurious insects will not only help to interest them in the farm but will prepare the way for further biologic study.

The large number of books and papers dealing with the life activities of common animals and giving the results of observations and experiments with plants makes it possible to apply the second part of Agassiz's oft repeated maxim, "Study nature and refer to books." But the responsibility rests on the teacher to see to it that nature is always studied first.

Teachers who are dissatisfied with the anatomic study of types, and who have not been able for lack of time or training to change, will find many valuable suggestions in the paper of Prof. C. F. Hodge on "Dynamic Biology in the High School," where he attempts to preserve the best features of the type system and combine with it the study of living plants and animals, either in the field or laboratory. Among other things Dr Hodge lays special stress on the study of practical problems, as the development and destruction of mosquitos, San José scale and of fungus diseases as the black knot of plums, also the study of bacteria in relation to health and disease. The "research-wise" method of study gave him the best results both in interest and development of the pupil.

Teachers sometimes complain that the pupils are too enthusiastic, but the real teacher of biology can use all the enthusiasm and every other means for developing an interest in the living world about us, but the interest should lead to investigation.

With the new syllabus for the biologic sciences in the high schools of this State before us, the question, what can the small school do with it, demands an immediate answer. One teacher of science is available and in some cases for only a part of his time. He is frequently trained only in physics and chemistry. There is little doubt that if a teacher is well trained in any observational science he might become qualified to teach the elements of the biologic sciences by attending such summer courses as are offered at Woods Hole, Cold Spring Harbor and Ithaca.

The skilful teacher will be content if his pupils are growing in power of observation, in self-reliance and judgment even if they can not glibly repeat a large number of facts.

The value of the remark of Agassiz that "a lead pencil makes a good microscope" is abundantly verified in the experience of every laboratory instructor. The attempt to draw a specimen is only second to modeling in stimulating the powers of observation. The drawing represents the object in two dimensions, while the model must show it in three. Every specimen should be drawn or modeled.

After observation comes comparison and for this purpose the superficial examination of many forms related to those carefully studied gives a breadth and fulness of knowledge not to be gained by the exhaustive study of a few types as is done in the fern-earthworm method.

A growing subject taught by a well trained and enthusiastic teacher who considers the development of the individual pupil of first importance, while the information is held to a second place, can not fail to stimulate the pupil to do his best.

The teacher who is impatient and irritated at the mistakes of his pupils may easily develop in them a distaste for all knowledge.

The point of view is of the greatest importance in biology, that of looking at every organism in its relations to others and to life. The facts accumulated by observation and the results of experiment should serve as centers about which the results of the observations of later life will naturally cluster.

It is sometimes said that mathematics is rarely taught—only arithmetic, algebra and geometry—for the whole is forgotten in its parts. In the same way, it is to be regretted that biology has in some cases been lost in botany, zoology and physiology, each taught by specialists who give little or no attention to the broad underlying principles of biology.

In the high school the oneness of all living phenomena of living organisms should be emphasized, for this gives the keynote to all later work.

As has been said, "Physiology is no mere memory science but one not only of observation but also of experiment."

Mr Peabody, and many others have demonstrated the practicability of requiring experimental work of pupils in the high school. A few facts learned experimentally are worth scores simply memorized.

Many observations can be made on our own bodies and, as Prof. C. W. Dodge has shown, experiments on living animals and plants will fix the main principles needed to explain human physiology.

Hygiene should come early in the grades and in the home as a purely informational subject, but physiology can not be treated satisfactorily except in an elementary way until the pupil has studied physics and chemistry.

The examinations set in biologic subjects usually test the memory, although in some cases the powers of observation are tested by the use of some plant or animal related to a form already studied. No directions are supplied, and it is preceded by a memory test which constitutes about three fourths of the examination. Questions which involve the application of some general principle to be illustrated by previous work in the laboratory, field or museum will test the judgment as well as the memory.

A few colleges are now not only requiring for entrance properly accredited notebooks, but give tests in the use of instruments and power of observation in describing animals and plants.

The coordination of nature study, work in school gardens and biology of the high school and college is progressing slowly and there is much yet to be done to gain the best results for the time and labor expended.

Harvard was the pioneer in accepting science work in physics done in the preparatory school by requiring conformity to a prescribed syllabus of experiments.

College courses have now been adjusted in many cases to accept and use the work of the best high schools in the biologic sciences. Even if the college can not give advanced standing in these subjects it is feasible to allow entrance credits for work satisfactorily done in the high school and thus give better courses in zoology, botany and physiology in the college.

With many problems awaiting consideration or partially worked out we may still be gratified with the progress already made and gather strength and encouragement for renewed effort.

In this State the splendid example of the biologic work in the high schools of Greater New York and the opportunities for the preparation of teachers of biology offered by the Teachers College, the syllabus in the biologic sciences prepared by a committee of New York teachers and adopted by the State, and the suggestive book of Lloyd and Bigelow on *Teaching Biology* lead us to believe that the improvement in preparation of teachers and in methods and equipment, in the next decade will far exceed that of the past.

We may lose in the exactness of purely anatomic study, but we shall gain in breadth of outlook and be able to realize more perfectly that we are a part of the great world of living organisms and that however splendid the endowment given us by the Creator, it is our privilege to advance farther on the road of progress than any who have preceded us. We may stand on the shoulders of the intellectual giants of the past and look on broader horizons and work for the advancement and ennoblement of those who are to follow. We should not, however, forget that if our opportunities are unimproved nature's inflexible laws will destroy us as degenerates.

Section D—MATHEMATICS

BY E. D. ROE JR, SYRACUSE UNIVERSITY

It seems paradoxical that one of the oldest of the sciences, the ideal of all the sciences, and one of the most alive in research, should have been the last one to acquire membership in this association of sciences. Whatever the explanation of this may be, it is a fact that on this decennial anniversary the section for mathematics celebrates its third birthday and second public appearance on the program stage. On this account you will not therefore care for a 10 year retrospect of the section leading back into minus eight years. Of the two positive years work completed, we feel sure that they will compare favorably with that of any like association for the same time and under equal conditions.

To discuss the past of our science in general with its wonderful conquests in research would take altogether too long, if it were not entirely irrelevant to the present meeting. In short what is there for us to do but to report that we are here in vigorous health, that we take pretty solid food already, that we are rapidly growing, that we are glad that we are here, that we thank you for the courtesies you have shown us, and that for the future we promise to make the section for mathematics worthy of that divine science which has called us, and worthy of this association of sciences.

To the future, then, we must devote our thoughts, instead of to a retrospect.

1 What then are our aims?

2 How shall we attain them?

With reference to the first question it would seem then, that the aim of the section for mathematics should be primarily to advance the pedagogy of mathematics in the broadest sense, while the element of research though not neglected should be a secondary one. The American Mathematical Society exists primarily for research, though a movement for pedagogy has had its origin in this society and has been taken up by its members in the formation of societies devoted to the pedagogy of mathematics. Thus the fields are clearly marked out. In fact attention may be called to a great pedagogical movement in mathematics which has recently sprung up. A few years ago Professor Klein, the eminent mathematician of Göttingen, began to turn his attention to the pedagogy of mathematics. New pedagogical journals for the subject appeared in Europe, and interest increased in the subject there. The Perry movement followed. A presidential address of the American Mathematical Society dealt with the whole subject in 1902. There soon followed the organization of distinct associations of teachers of mathematics in this country, e. g. of the Middle States and Maryland, of New England, of Ohio, of the Middle West, of the Pacific coast, etc. In each of these the leading spirits were members of the American Mathematical Society. The mathematical part of that new pedagogical journal *School Science and Mathematics* has appeared as an expression of this movement. And lastly a movement toward the federation of all the associations (to include science associations on the suggestion of the latter) is now under consideration, with the suggestion that *School Science and Mathematics* be made the official organ of the federation societies.

It seems to me that federation for the purpose of securing such legislation systematically and uniformity of all reforms in the courses and methods of teaching, and in the qualifications of teachers of mathematics as are shown by the discussions and consensus of the federated societies to be necessary, should be the goal towards which we should work.

While discussion and interchange of views will enable us who participate to detect our individual defects, and to become acquainted with better methods, yet some of the fundamental reforms that are needed can only be brought about by enactment of Legislatures, making it impossible for certain things to be continued as they are and requiring uniform standards of qualification and preparation on the part of teachers of mathematics in our secondary schools, that shall place all our secondary teachers and secondary education on a plane as high, say, as that of the secondary teachers and secondary education of Germany.

It would seem to me, then, that for the section in mathematics, the answers to our two questions are these:

Our aim should be primarily to advance the pedagogy of mathematics in its broadest sense. Secondarily we should make a place for such of the latest researches of mathematics as can be suitably brought before us. And we should do these two things in a manner worthy of the Empire State, and among state associations we should aspire to that leadership which we all agree is the Empire State's due in the affairs of the nation. We have the mathematicians in the State of New York to do this.

To the second question as to how these aims are to be attained, I would answer, by discussions, by enthusiasm, by loyalty, by personal work in extending our membership, by reports on the latest investigations which affect the philosophy and foundations of mathematics, and on such other research work as may from time to time be suitably introduced, and last and above all, by affiliating ourselves with a federated movement, when that shall materialize which shall have for its object the securing by legislation of such mathematical reforms as may be deemed needed after careful discussion, experimental trial where necessary, and the consensus of the leading mathematical teachers of the country.

MEMBERS 1906

When the name of an institution includes the name of its town or city the latter is not repeated. Where no state abbreviation is given, New York is to be understood.

Alverson, Burt W., Dexter
Arey, Albert L., Girls High School, Brooklyn
Atkinson, George F., Cornell University, Ithaca

Babcock, Edward L., Alfred University
Baker, A. M., Irondequoit
Bardwell, D. L., superintendent of schools, Borough of Richmond
Barker, V. K., Turin
Barrows, Franklin W., 1364 Michigan st. Buffalo
Barrus, R. M., Keuka College
Beach, Grace B., Normal College of the City of New York
Bean, Charles M., Pulaski High School
Bennett, William M., 76 Wellington av. Rochester, High School
Bentley, Gordon N., University of Tennessee, Knoxville, Tenn.
Benway, Mabel R., North Tonawanda High School
Betz, William, East High School, Rochester
Bigelow, Maurice A., Teachers College, New York
Binns, Charles F., New York State School of Clay-working and Ceramics, Alfred
Bishop, Irving P., State Normal School, Buffalo
Bogert, Marston T., Columbia University, New York
Bond, W. E., State Normal School, Potsdam
Boniface, Sister M., Nazareth Academy, Rochester
Bradley, Theodore J., Albany College of Pharmacy
Brigham, A. P., Colgate University, Hamilton
Bronson, B. S., State Normal School, Geneseo
Bryant, Frank L., Erasmus Hall High School, Brooklyn
Bullard, W. G., 613 S. Crouse av. Syracuse
Burgin, Bryan O., Albany High School
Burlingham, Gertrude C., Binghamton High School
Burr, Charles H., White Plains High School
Butler, Alfred M., Schenectady High School
Byrnes, Esther F., Girls High School, Brooklyn

Caldwell, L. Jay, East Orange, New Jersey, High School
Callahan, E. B., Little Falls High School
Campbell, Daniel R., Rome High School
Campbell, Jessie R., West High School, Rochester
Case, L. V., Washington Irving High School, Tarrytown
Cate, Eleazar, 15 Harcourt st. Boston, Mass.
Cattell, J. McKeen, Garrison-on-Hudson
Chesebrough, Thomas U., Yonkers High School
Chester, W. M., Colgate University, Hamilton
Churchill, Edmund P., Washington Irving High School, Tarrytown
Clark, O. D., Boys High School, Brooklyn
Clement, Arthur G., Education Department, Albany
Clendenin, W. W., Wadleigh High School, New York
Cobb, Charles N., Education Department, Albany
Comstock, J. H., Cornell University, Ithaca
Conant, O. P., 70 5th av. New York
Congdon, E. D., Malone
Cooley, LeRoy C., Vassar College, Poughkeepsie
Cornish, William A., State Normal School, Cortland
Crawford, A. Myrtella, Central High School, Buffalo
Curtiss, Harriette A., Sodus High School

Dann, Mary E., Girls High School, Brooklyn
Davis, William H., Elmira Free Academy

Denham, Henry H., Commercial High School, Syracuse
Dodge, Charles W., University of Rochester
Dodge, Richard E., Teachers College, New York
Dunham, Frank F., Canisteo High School
Dunn, Joseph G., Adelphi Academy, Brooklyn

Elliott, Arthur H., Laboratory Consolidated Gas Co., 21st st. & Avenue A, New York
Emmons, Fred E., Olean High School

Failing, Wilson R., Port Chester High School
Fairbanks, Floyd C., Geneva High School
Farnham, Amos W., State Normal School, Oswego
Fitsworth, Waldo, Alfred Academy
Folsom, Frances L., Technical High School, Buffalo
Ford, E. E., LeRoy High School
Fowler, G. W., Little Falls High School
Freley, J. W., Wells College, Aurora

Gage, Simon H., Cornell University, Ithaca
Gager, C. Stuart, State Normal College, Albany
Gary, Lester B., Central High School, Buffalo
Greene, W. J., South Glens Falls High School

Hahn, Clarence W., High School of Commerce, New York
Hale, Albert C., Boys High School, Brooklyn
Hall, James H., Syracuse High School
Hall, Mabel B., Hoosick Falls High School
Hallock, William, Columbia University, New York
Hancock, W. J., Erasmus Hall High School, Brooklyn
Hanna, Jennie P., 731 E. Main st. Rochester
Hargitt, Charles W., Syracuse University
Hargitt, George T., 909 Walnut av. Syracuse
Harris, C. Everett, East High School, Rochester
Hartel, William, Lafayette High School, Buffalo
Hayner, B. A., Canandaigua High School
Henderson, Royal L., Nyack High School
Henshaw, Hoyt, Stockton
Herrick, Lillian B., Elmira Free Academy
Hersey, C. Brooks, Masten Park High School, Buffalo
Hill, R. V., Jamestown High School
Hine, Lewis W., 33 Central park west, New York, Ethical Culture School
Hopkins, Rupert H., Curtis High School, West New Brighton, New York
Hopkins, T. C., Syracuse University
Howes, H. L., Cook Academy, Montour Falls
Hudson, George H., State Normal School, Plattsburg
Huested, F. P., Albany High School
Hunt, Arthur E., Manual Training High School, Brooklyn
Huntington, F. W., Erasmus Hall High School, Brooklyn

Jaquish, Ben M., 681 E. 21st st. Brooklyn
Jenks, L. E., Ogdensburg High School
Jewett, Franklin N., State Normal School, Fredonia
Johnson, Julius M., Morris High School, New York
Jones, H. B., Binghamton High School

Keller, Christopher, Luzerne High School
Kelly, Henry A., Ethical Culture School, New York
Kemp, James F., Columbia University, New York
Kenyon, O. C., Syracuse High School
Kingsley, Clarence D., Manual Training High School, Brooklyn
Kirchwey, Clara B., Teachers College, New York
Kirkwood, J. E., Syracuse University
Kittredge, R. J., 446 W. 7th st. Erie, Pa.
Kraus, E. H., University of Michigan, Ann Arbor, Mich.

Lamson, F. L., University of Rochester
Langworthy, William F., Colgate Academy, Hamilton
Lee, Frederic S., Columbia University, New York
Lee, Glenn M., Cook Academy, Montour Falls
Lennon, W. H., State Normal School, Brockport
Linville, Henry R., Dewitt Clinton High School, New York
Lockwood, Cornelius W., Newburgh Academy
Loeb, Morris, 273 Madison av., New York University
Logan, Mrs Mary C., Lyons High School
Longwell, Elizabeth J., Penn Yan
Lovell, Thomas B., Niagara Falls High School
Lyon, Howard, State Normal School, Oneonta

McKay, John S., Packer Collegiate Institute, Brooklyn
Mackenzie, Mary D., Saratoga Springs High School
McMahon, James, Cornell University, Ithaca
Mann, Warren, Potsdam Normal School
Marcella, Sister M., Nazareth Academy, Rochester
Martin, Jennie T., Central High School, Buffalo
Maury, Mytton, Hastings on Hudson
Mellin, Calvert K., Central High School, Buffalo
Merrell, William D., University of Rochester
Merritt, E. G., Lafayette High School, Buffalo
Metzler, W. H., Syracuse University
Miller, Gertrude, Penn Yan Academy
Milliman, Lennette, 70 Melrose st. Rochester, High School
Minchin, Howard D., University of Rochester
Moore, J. C., Cattaraugus High School
Moore, Katherine R., The Greenwich School, 95 Putnam av. Greenwich, Ct.
Moore, S. G., Dannemora
Morrey, William T., Morris High School, New York
Morrill, A. D., Hamilton College, Clinton
Morse, Charles F., Dewitt Clinton High School, Brooklyn
Morse, H. L. F., Troy High School

Naughton, John A., Albany High School
Newman, Hugo, Public School 33, The Bronx, New York
Nichols, Edward L., Cornell University, Ithaca

O'Brien, Abigail, Watertown High School
O'Neill, Everett, Education Department, Albany
Osborn, Henry F., Columbia University, New York
Overacker, Minnie L., Syracuse High School
Overton, Frank, Patchogue, L. I.

Paddock, Bertha L., Franklin Academy, Malone
Palmer, F. D., Jamestown High School
Palmer, Lelia B., Utica Free Academy
Pattee, Ernest N., Syracuse University
Peabody, James E., Morris High School, New York
Peckham, W. C., Adelphi College, Brooklyn
Perine, Eunice, State Normal College, Albany
Pierce, Elizabeth A., Fairport High School
Piper, P. F., Central High School, Buffalo
Pollock, Horatio M., State Civil Service Commission, Albany
Porter, Eva M., Herkimer High School
Porter, R. A., Syracuse University
Pratt, H. Irving, school commissioner, Orwell

Radcliffe, Lewis, Port Jervis High School
Record, Mrs Carrie L., State Normal School, Fredonia
Reed, F. W., West Jersey Academy, Bridgeton, New Jersey
Robertson, C. B., State Normal School, Cortland
Robinson, Emma C., 426 S. 1st av. Mt Vernon
Roe, E. D., Syracuse University
Rogers, C. G., Syracuse University

Sadler, Nettie M., 907 University av. Syracuse
Schmitz, H. J., State Normal School, Geneseo
Scott, Irving D., 215 Erie st. Syracuse
Share, William W., Adelphi College, Brooklyn
Shatz, Josephine, Rochester High School
Shear, S. R., superintendent of schools, Kingston
Shearer, John S., Cornell University, Ithaca
Sheldon, C. S., State Normal School, Oswego
Sherwood, Alfred B., Poughkeepsie High School
Sherwood, Leora E., Syracuse High School
Sieberg, W. H. J., Hotel Winthrop, 7th av. & 125th st. New York, School 43
Sisson, E. P., Colgate Academy, Hamilton
Smallwood, W. M., Syracuse University
Smith, Ernest R., Syracuse High School
Smith, H. Monmouth, Syracuse University
Smith, Kendall P., Perry High School
Smith, Oren R., Windham High School, Willimantic, Ct.
Sohon, M. D., Morris High School, New York
Stannard, J. Ellis, Owego High School
Stetson, Orlando S., Syracuse University
Stoel, Thomas B., Sackett High School, Sacketts Harbor
Stoller, James H., Union College, Schenectady
Streater, Katherine, Lafayette High School, Buffalo

Tanner, J. H., Cornell University, Ithaca
Tarr, Ralph S., Cornell University, Ithaca
Taylor, Joseph S., 2275 Aqueduct av. University Heights, New York
Taylor, J. F., Olean High School
Tether, C. H., State Normal and Training School, Oswego
Thomas, M. Smith, Central High School, Buffalo
Tompkins, Elizabeth M., Poughkeepsie High School
Trant, Amelia E., Masten Park High School, Buffalo
Traxel, Emma J., New London High School
Tufts, F. L., Columbia University, New York
Turner, George M., Masten Park High School, Buffalo

Van Arsdale, May B., Teachers College, New York
Vickery, Stephen A., Gloversville High School
Viertel, Samuel, 15 Kosciusko st. Brooklyn
Voegelin, Carl O., High School, Newark, New Jersey
vonNardroff, E. R., Erasmus Hall High School, Brooklyn

Wardwell, Mary L., Central High School, Buffalo
Watson, B. M., Syracuse High School
Weatherlow, J. K., Education Department, Albany
Weed, Henry T., Manual Training High School, Brooklyn
Wetmore, E. W., State Normal College, Albany
Whitney, E. R., Binghamton High School
Wickes, W. K., principal, Syracuse High School
Wilcox, C. C., Starkey Seminary, Eddytown
Wilder, Burt G., Cornell University, Ithaca
Wilder, George F., Erasmus Hall High School, Brooklyn
Williams, Mary E., Cortland High School
Williston, Arthur L., Pratt Institute, Brooklyn
Winslow, E. J., Elmira Free Academy
Woodhull, John F., Teachers College, New York
Woodworth, Philip B., Lewis Institute, 5808 Ohio st. Chicago, Ill.
Wright, Isaac M., Westfield High School

INDEX

Action, summary of, 7-9
Algebra, nature of applied problems, by D. E. Smith, 92-98; purpose and method of study in our secondary schools, by E. P. Sisson, 98-102; elementary, graphic methods in, by William Betz, 102-7
Alternating current, 27-31
Arithmetic, 93-94
Arnold, Matthew, quoted, 90

Berthelot, quoted, 74-75
Betz, William, Graphic Methods in Elementary Algebra, 102-7
Bigelow, M. A., quoted, 33
Biological survey of New York State, action on, 7; paper by C. W. Dodge, with discussion, 9-16
Biology, 76-84; high school, settled and unsettled problems, 31-40; research and graduate work for teachers in high schools, by E. F. Byrnes, 80-84; progress in, by A. D. Morrill, 112-17
Birds, teaching of, from the economic standpoint, by J. M. Johnson, 76-79
Bishop, F. L., quoted, 23-24, 25-26
Bishop, I. P., report on teaching physiology presented by, 9
Byrnes, Esther F., Research and Graduate Work for Teachers of Biology in High Schools, 80-84; demonstration by, 84

Chemistry, teaching in the secondary schools, by W. C. Geer, 45-59; some chemical experiments to illustrate the New York State syllabus for *1906*, by J. F. Woodhull, 69
Chester, Wayland M., Settled and Unsettled Problems in High School Biology, 31-40
Clarke, John M., on biological survey of New York, 15-16
Cobb, C. N., report presented by, 9; opening of discussion on syllabus in physical geography, 40-41
Committees, reports, 9
Coulter, J. M., quoted, 32-33

Demonstrations, 84
Dodge, Charles Wright, A Proposed Biological Survey of New York State, 9-15
Dryer, Charles R., quoted, 86

Earth science, 40-44
Earth science, history and culture, by E. E. Perine, 84-92
Electricity, the alternating current, 27-31
Eliot, Pres., quoted, 90

Federation of teachers organizations, 7

Geer, William C., Teaching of Chemistry in the Secondary Schools, 45-59
Geography, *see* Earth science
Gilman, quoted, 86
Greenwood, quoted, 25

Hahn, C. W., demonstration by, 84
Hallock, William, on 10 years progress in physics, 108-12
Hodge, C. F., quoted, 36
Hopkins, T. C., Nebular and Planetesimal Hypotheses to Account for the Origin of the Earth, 41-44
Huxley, quoted, 80

Johnson, J. M., The Teaching of Birds from the Economic Standpoint, 76-79
Jones, F. T., quoted, 21-22

Kirkwood, J. E., demonstration by, 84

Laboratory course in physiology, report on, 9
Laboratory exercises in physiography, report of committee on, 92. *See also* Biology; Chemistry; Physiology.
Liquid air, 63-68
Long, Edith, quoted, 18

McMahon, James, Correlation of Mathematics and Physics, 17-27
MacMurray, Charles, quoted, 85
Mathematics, 92-107; two schools of, 92-93; progress in, by E. D. Roe jr, 118-20
Mathematics and physics, correlation of, 17-27
Meikeljohn, quoted, 75
Metric system, action on, 7
Morrill, A. D., on 10 years progress in biology, 112-17
Myers, G. W., quoted, 20-21

Nebular and planetesimal hypotheses to account for the origin of the earth, by T. C. Hopkins, 41-44

Officers for *1906*, 8

Parker, Col., quoted, 87
Perine, Eunice E., Earth Science, History and Culture, 84-91
Physical geography, opening of discussion on syllabus in, 40-41
Physics, the alternating current, 27-31; some properties of matter at low temperature, by J. S. Shearer, 59-68; 10 years progress in, by William Hallock, 108-12; second year, committee continued, 9
Physics and mathematics, correlation of, 17-27
Physiography, report of committee on laboratory exercises in, 92
Physiology, joint committee on teaching, report, 9; laboratory course in, report on, 9
Planetesimal hypothesis to account for the origin of the earth, 41-44

Raymond, Dean, quoted, 25
Roe, E. D. jr, on progress in mathematics, 118-20

Science teaching, some pedagogical phases, by E. R. Whitney, 69-75
Section officers for *1906*, 8
Shearer, J. S., Some Properties of Matter at Low Temperature, 59-68
Sisson, E. P., Purpose and Method of the Study of Algebra in our Secondary Schools, 98-102
Smith, David Eugene, Nature of Applied Problems in Algebra, 92-98
Sykes, Mabel, quoted, 19-20
Symonds, John Addington, quoted, 90

Teachers organizations, federation, 7
Treasurer's report, 8

Wharton, Sir William, quoted, 85
Whitney, E. R., Some Pedagogical Phases of Science Teaching, 69-75
Woodhull, John F., The Alternating Current, 27-31; Some Chemical Experiments to Illustrate the New York State Syllabus for *1906*, 69
Woodworth, quoted, 25

Published monthly by the
New York State Education Department
BULLETIN 417 AUGUST 1907

Secondary Education

Bulletin 34

NEW YORK STATE SCIENCE TEACHERS ASSOCIATION

PROCEEDINGS OF THE

ELEVENTH ANNUAL CONFERENCE

Held at Teachers College, New York city, December 26 and 27, 1906

IN CONJUNCTION WITH AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND OTHER AFFILIATED SOCIETIES

PAGE
Officers 1906 ... 3
Officers 1907 ... 3
Council ... 3
Summary of sessions ... 4
Summary of action ... 8
Addresses and papers ... 10
High School Courses in Science: H. A. KELLY ... 10
Section meetings
Section A — Physics and chemistry
More Interesting and Practical Mechanics for the High School: J. M. JAMESON ... 23
Section B — Biology
Biology as Method and as a Science in Secondary Schools: H. R. LINVILLE ... 30
Section C — Earth science
Field Work in Physical Geography: JENNIE T. MARTIN ... 39
The Value of the Inductive Study of Relief Forms in Field Work and Contour Maps: W. H. PLATZER ... 42
Section D — Mathematics
The Place of the Theory of Transformations in Geometry: A. S. GALE ... 47
Concerning the Introduction of Modern Notions into the Geometry of Secondary Schools: C. J. KEYSER ... 52
General session ... 62
The Preparation of the Teacher of Mathematics in Secondary Schools: D. E. SMITH ... 62
Science Teaching Seen from the Outside: E. L. THORNDIKE ... 69
Section A — Physics and chemistry
The New Movement for the Reform of Physics Teaching in Germany, France and America: C. R. MANN ... 75

PAGE
Section B — Biology
Plant Physiology in Secondary Schools: J. Y. BERGEN ... 100
The Established Principles of Nature Study: M. A. BIGELOW ... 105
The Teaching of Biological Sciences in Some of the High Schools in New York State: L. B. GARY ... 111
Biological Sciences in Syracuse High School: G. T. HARGITT ... 117
Section C — Earth science
The Study of Minerals and Rocks in Physical Geography in the High School: C. H. RICHARDSON ... 120
Barschois, Bar and Tickle: J. M. CLARKE ... 123
The Relation Which School Gardens May Bear to Industrial and Commercial Geography: A. W. FARNHAM ... 132
Reference Books and Physical Geography Teaching: W. T. MOREY ... 140
Section D — Mathematics
Secondary Mathematics from a College Standpoint: H. E. HAWKES ... 145
What Equipment is Needed for the Effective Teaching of High School Mathematics? C. E. BIXLER ... 151
The Relation between High School and College Mathematics: H. E. WEBB ... 159
Recent Tendencies and Open Questions in the Teaching of Elementary Geometry: W. BETZ ... 170
American Federation of Teachers of the Mathematical and the Natural Sciences: C. R. MANN ... 175
Members 1907 ... 178
Index ... 183

ALBANY
NEW YORK STATE EDUCATION DEPARTMENT
1907

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STATE OF NEW YORK
EDUCATION DEPARTMENT

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With years when terms expire

1913	Whitelaw Reid M.A. LL.D. *Chancellor*	New York
1917	St Clair McKelway M.A. LL.D. *Vice Chancellor*	Brooklyn
1908	Daniel Beach Ph.D. LL.D.	Watkins
1914	Pliny T. Sexton LL.B. LL.D.	Palmyra
1912	T. Guilford Smith M.A. C.E. LL.D.	Buffalo
1918	William Nottingham M.A. Ph.D. LL.D.	Syracuse
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1911	Edward Lauterbach M.A. LL.D.	New York
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New York State Education Department

Secondary Education

Bulletin 34

NEW YORK STATE SCIENCE TEACHERS ASSOCIATION

PROCEEDINGS OF THE

11th ANNUAL CONFERENCE

Held at Teachers College, New York city, December 26 and 27, 1906

IN CONJUNCTION WITH AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND OTHER AFFILIATED SOCIETIES

OFFICERS FOR 1906

J. F. Woodhull, *President*, Teachers College, New York city
E. D. Roe, *Vice President*, Syracuse University
J. E. Stannard, *Secretary-Treasurer*, Greenwich (Ct.) High School

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J. S. Shearer, *President*, Cornell University, Ithaca
E. D. Roe, *Vice President*, Syracuse University
J. E. Stannard, *Secretary-Treasurer*, Adelphi Academy, Brooklyn

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1910 G. M. Turner, Masten Park High School, Buffalo
T. C. Hopkins, Syracuse University
Charles Newell Cobb, Education Department, Albany
1909 A. P. Brigham, Colgate University, Hamilton
C. E. Harris, East High School, Rochester
Howard Lyon, Oneonta Normal School
1908 L. V. Case, Washington Irving High School, Tarrytown
W. T. Morrey, Morris High School, New York city
J. S. Shearer, Cornell University, Ithaca
1907 A. W. Farnham, Oswego Normal School
F. L. Bryant, Erasmus Hall High School, Brooklyn
J. E. Kirkwood, Syracuse University

SUMMARY OF SESSIONS

WEDNESDAY, DECEMBER 26

2.30 p. m. General meeting. Room 411

Association called to order by the retiring president, ALBERT P. BRIGHAM, Colgate University, Hamilton

Introduction of *President-elect* JOHN F. WOODHULL, Teachers College, Columbia University, New York city

Address of welcome

DEAN JAMES E. RUSSELL, Teachers College, Columbia University, New York city

3.20 p. m.

Address: Are High School Courses in Science Adapted to the Needs of Adolescents?

HENRY A. KELLY, Ethical Culture School, New York city

4 p. m. Section meetings

Section A — Physics and chemistry. Room 411. C. E. HARRIS, East High School, Rochester, *Chairman;* G. M. TURNER, Buffalo, *Secretary*

Demonstration: More Interesting and Practical Mechanics for the High School

J. M. JAMESON, Pratt Institute, Brooklyn

Section B — Biology. Room 300. ESTHER F. BYRNES, Girls High School, Brooklyn, *Chairman;* WAYLAND M. CHESTER, Colgate University, Hamilton, *Secretary*

Biology as Method and as a Science in Secondary Schools

HENRY R. LINVILLE, De Witt Clinton High School, New York city

Section C — Earth science. Room 200. T. C. HOPKINS, Syracuse University, *Chairman;* JENNIE T. MARTIN, Central High School, Buffalo, *Secretary*

1 Field Work in Physical Geography

JENNIE T. MARTIN, Central High School, Buffalo

2 The Value of the Inductive Study of Relief Forms in Field Work and Contour Maps

WILLIAM H. PLATZER, Poughkeepsie High School

Section D — Mathematics. Room 211. WILLIAM BETZ, East High School, Rochester, *Chairman;* F. L. LAMSON, University of Rochester, *Secretary*

1 The Place of the Theory of Transformations in Geometry
A. S. GALE, University of Rochester

2 Concerning the Introduction of Modern Notions into the Geometry of Secondary Schools
C. J. KEYSER, Columbia University, New York city

5 p. m. Meeting of the council. Room 413

8 p. m. General session. Room 117

Address: The Preparation of the Teacher of Mathematics in Secondary Schools
DAVID EUGENE SMITH, Teachers College, Columbia University, New York city

Address: Science Teaching Seen from the Outside
EDWARD L. THORNDIKE, Teachers College, Columbia University, New York city

THURSDAY, DECEMBER 27

9.30 a. m. Section meetings

Section A — Physics and chemistry. Room 411. C. E. HARRIS, East High School, Rochester, *Chairman*

1 The New Movement for the Reform of Physics Teaching in Germany, France and America
C. R. MANN, Chicago University

10.15 a. m.

2 Report of the Committees of this Association on the New Move among Physics Teachers
JOHN F. WOODHULL, *Chairman*

10.30 a. m.

3 Purpose of Science in the Culture of Adolescent
SHERMAN DAVIS, Indiana University

Section B — Biology. Room 300. ESTHER F. BYRNES, Girls High School, Brooklyn, *Chairman*

1 Plant Physiology in Secondary Schools
JOSEPH Y. BERGEN, Cambridge, Mass.

2 The Established Principles of Nature Study
MAURICE A. BIGELOW, Teachers College, Columbia University

3 The Teaching of Biological Sciences in Some of the High Schools in New York State
LESTER B. GARY, Central High School, Buffalo

4 Biological Science in Syracuse High School
GEORGE T. HARGITT, Syracuse High School

Section C — Earth science. Room 200. T. C. HOPKINS, Syracuse University, *Chairman*

1 The Study of Minerals and Rocks in Physical Geography in the High School
C. H. RICHARDSON, Syracuse University

2 Barachois, Bar and Tickle
JOHN M. CLARKE, State Geologist, Albany

3 The Relation which School Gardens may Bear to Industrial and Commercial Geography
AMOS W. FARNHAM, Oswego State Normal School

4 Reference Books and Physical Geography Teaching
WILLIAM T. MORREY, Morris High School, New York city

Section D — Mathematics. Room 211. WILLIAM BETZ, East High School, Rochester, *Chairman*

1 Secondary Mathematics from a College Standpoint
H. E. HAWKES, Yale University, New Haven, Ct.

2 What Equipment is Needed for the Effective Teaching of High School Mathematics?
C. E. BIKLE, Horace Mann High School, New York city

3 The Relation between High School and College Mathematics
H. E. WEBB, Stevens Institute, Hoboken, N. J.

2 p. m. Section meetings

Election of section officers and miscellaneous business

Section A — Physics and chemistry. Room 411. Teachers College. C. E. HARRIS, East High School, Rochester, *Chairman*

Demonstration: Optical Oddities
WILLIAM HALLOCK, Columbia University

Section C — Earth science. Room 200. T. C. HOPKINS, Syracuse University, *Chairman*

Laboratory Exercises in Physical Geography — Illustrated
W. M. DAVIS, Harvard University

Section D — Mathematics. **Room 211.** **William Betz,** East High School, Rochester, *Chairman*

1 Recent Tendencies and Open Questions in the Teaching of Elementary Geometry
W. Betz, East High School, Rochester

2 American Federation of Teachers of the Mathematical and the Natural Sciences
C. R. Mann, University of Chicago

3.15 p. m. General meeting. Room 411

1 Report of treasurer
2 Report of auditing committee
3 Report of nominating committee, election of officers, announcement of place of next meeting
4 Necrology
5 Reports of standing committees and delegates
6 Miscellaneous business

4 p. m.

Address: West Indian Volcanos and their Recent Eruptions, illustrated
E. O. Hovey, American Museum of Natural History

8 p. m.

Union meeting with the American Association for the Advancement of Science in the Auditorium of the Horace Mann School
Presidential address:
C. M. Woodward, St Louis

9 p. m.

Reception given by trustees of Columbia University

SUMMARY OF ACTION

Treasurer's report

Summary as per books and vouchers on file for year ending December 27, 1906

Receipts

Dec. 29, 1905 Cash on hand	$92 43
Dec. 27, 1906 Dues to date	142 ..
Total	$234 43

Expenditures

Dec. 27, 1906 Total to date	$86 34
Dec. 27, 1906 Balance on hand	148 09
	$234 43

Auditing committee. We, the undersigned, regularly appointed auditing committee of the New York State Science Teachers Association have examined the report and accounts of Treasurer Stannard and desire to report that we find them correct in every detail.

W. W. Clendenin
R. H. Cornish

December 27, 1906
Report accepted

Section officers for 1907

Section A — Physics and chemistry

Chairman (not reported)

Section B — Biology

Chairman, Esther Byrnes, Girls High School, Brooklyn
Secretary, W. M. Chester, Colgate Academy, Hamilton

Section C — Earth science

Chairman, Jennie T. Martin, Central High School, Buffalo

Section D — Mathematics

Chairman, W. A. Cornish, Cortland Normal School

The executive council appointed J. S. Shearer to act as our representative at a meeting of the American Federation of the Teachers of Science and Mathematics, Thursday afternoon, December 27. [*See* report of meeting on p. 175.]

Place of meeting

An invitation was extended to the association to meet at Cornell University, Ithaca, next December.

Motion made to meet in Ithaca the latter part of Christmas week, December 1907.

Motion carried.

Necrology

O. D. CLARK, G. W. Curtis High School, Staten Island, died in July 1906. Mr Clark was a member of the executive council.

Reports of committees

Federation. No report. Committee continued.

New move among physics teachers. The committee reports progress but the work must extend through a number of years. Section A assumes charge of the committee and adds two new members. The following are members of the committee:

J. F. WOODHULL, Teachers College, New York
J. S. SHEARER, Cornell University, Ithaca
O. C. KENYON, Syracuse High School
E. S. WETMORE, Albany Normal College
L. E. JENKS, Ogdensburg High School

Biology. Committee reports progress and is continued.

Laboratory exercises in earth science. Report of committee was sent to the secretary between meetings and reference was made to it in last year's bulletin. Pamphlets containing list of laboratory exercises in earth science may be obtained by application to Education Department.

Committee discharged.

Biological survey project. The committee appointed to aid in the biological survey project made no report.

Committee continued.

Joint committee on physiology. Prof. I. P. Bishop, Buffalo Normal School, was continued as our representative on the joint committee on physiology.

Vote of thanks. A vote of thanks was extended to Teachers College for its hospitality.

ADDRESSES AND PAPERS

Wednesday afternoon, December 26

The association was called to order by the retiring president, Albert P. Brigham, Colgate University, Hamilton. After the introduction of President-elect John F. Woodhull of Teachers College, Columbia University, an address of welcome was given by Dean James E. Russell, Teachers College. After this the following papers were presented.

ARE HIGH SCHOOL COURSES IN SCIENCE ADAPTED TO THE NEEDS OF ADOLESCENTS?

BY HENRY A. KELLY, DIRECTOR OF BIOLOGY AND NATURE STUDY, ETHICAL CULTURE SCHOOL, NEW YORK CITY

I ask you to consider with me for a few moments this afternoon the question as to how far our high school courses in science are adapted to the needs of pupils in the years of early adolescence.

A few general statements concerning the aim and scope of school education may be of value in helping us to orient ourselves with reference to this question. School education is but one phase of the larger education of life, which, for the race, had its beginnings far back in the prehistoric past, and which, for the individual, may be considered to be synchronous with the period from birth till old age. In education, as in biology, kenogenesis modifies the ancient palingenetic record, establishing in each generation a new point of departure, hence school education at every stage should be built on the foundation of what has gone before, both in the history of the race and in the history of the individual. Not only should it be fitted to the pupil's needs at each stage of development, giving the physical, mental and moral culture which each age requires for its growth, but it should aim also to prepare the pupil to profit by the other educating influences of life outside of the school, and after the school period has ended. Januslike, it should look backward over the road the race has laboriously traveled to reach its present level, and forward toward the future.

We must inquire of our high school science work whether it utilizes to the full extent its opportunity to be of service in the large work of school education. Does it take account of the pupils' heritage from the past? Does it build its superstructure on the foundation of a knowledge of the instinctive reactions of adolescents in the realm of feeling, which are more fundamental and far older than reason, both phylogenetically and ontogenetically? Does it appeal to real vital human interests? Does it so choose its material that it fulfils its function as a propaedeutic to the larger life beyond the high school period? Does it help to fit the pupils not only to know the truth, but to really care for what is most worth caring for in life? Does it imbue with a love of truth, and fire with something of the reformer's enthusiasm and zeal in its pursuit? It must still be demanded that our high school work in science should train in habits of observation, in the ability to think logically, and in the power of clear and concise expression in the mother tongue; but it is beginning to be appreciated that the inclination toward the observation of natural phenomena rests on an emotional substratum, and that it is futile to attempt to teach clear thinking when interest does not furnish a motive to thought, and a reason for expression.

Though the teacher, as an artist, is dealing with a responsive material, which he is attempting to fashion in the light of an ideal, it is as necessary for him to be familiar with the fundamental facts of child development, as that the sculptor should know the physical properties of the marble which fit it for his purpose, or that the painter should know the results of the mixture of his pigments. Teachers in the secondary schools have shown in the past little attention to the study of the nature of the child in the adolescent period, giving point to Dr Burnham's criticism that, "while perhaps the greatest waste of time in the American schools occurs in the lower grades, the greatest waste of energy occurs during the period of high school and college education." It is difficult to see how this could be otherwise, in view of our ignorance of the forces at work at this period. Unless securely grounded in a knowledge of the principles which underlie child development, our high school education in science will be an uneconomical expenditure of time and energy and fail as a propaedeutic to life.

An examination of the body of information available, largely as a result of the child study movement, is likely at first sight to be disappointing. When an appraisal of the results of this study is made, they may seem either inadequate, platitudinous or lacking in application to our particular problem. We should remember, however, that only recently has special attention been given in this country to the careful study of the physical and psychical phenomena of adolescence. One of the important early contributions to this subject was Pres. G. Stanley Hall's, "The Moral and Religious Training of Children and Adolescents," published in the *Princeton Review* in 1882, and reprinted in the *Pedagogical Seminary* in 1891, in which volume also appeared Dr Burnham's valuable "Study of Adolescence." Since that time other important contributions have been made, several under the direction of President Hall, to whom we are also indebted for the monumental work on "Adolescence," recently published. A brief statement of some of the striking physical and mental characteristics of the adolescent may help us to see him in relation to the child that was, on the one hand, and to the man that is to be, on the other. It may serve to suggest an answer to some of the questions which have just been raised.

From birth till the age of 2½ years the growth of the young child is very rapid, especially during the first year. After 2½ years of age growth is slower and more nearly uniform. A slight period of retardation occurs from about 6 or 7 to 10 or 12 years. At the age of from 10 to 12 years in girls, and from 12 to 14 years in boys, occurs the acceleration in growth which marks the oncoming of the pubescent period. At about 18 years of age another period of retardation is to be noted, after which growth continues slowly to a time which is variously stated by different authorities.

In later childhood — the years from 8 to 12 — the boy and girl have reached a period of relative stability of mind and body. The health is usually good, and there is a great fund of reserve strength. The senses are keen, and perceptions acute. Interests are numerous and concrete. Reactions are impulsive; reason is but slightly developed.

Contrasted strongly with this period of relative stability is the ensuing stage of physical and psychical storm and stress. It is ushered in by the period of acceleration in growth, of which mention has just been made. Muscles and bones grow apace. The heart almost doubles in size, and the lungs greatly increase their capacity. The brain, which has grown but slowly since the eighth year, acquires nearly its adult size and weight. The voice changes; the all pervading influence of sex is felt. There is increased power to resist disease, though the period has its own special dangers; disorders of the alimentary canal are especially common; irregularities of the heart occur, and according to some authorities, there is special liability to infection by tuberculosis. The sleep is often restless and broken. Many cases of hysteria have been traced to existing causes at this period. Certain forms of insanity have been noted. Seventy-eight per cent of the cases of insanity at this period take the form of mania, while most of the others are due to melancholia.

To quote Dr Hall:

> Adolescence is a new birth, for the higher and more completely human traits are now born. The qualities of body and soul that now emerge are far newer . . . Development is less gradual and more saltatory, suggestive of some ancient period of storm and stress when ancient moorings were broken and a higher level attained . . . Important functions previously nonexistent arise. Growth of parts and organs loses its former proportions, some permanently and some for a season . . . It is the age of sentiment and of religion, of rapid fluctuation of mood, and the world seems strange and new. Interest in adult life and in vocations develops. Youth awakes to a new world and understands neither it nor himself.

Dr Burnham's investigations seem to point to the fact that this is the golden time for genuine interest in philosophical studies, for the adolescent is possessed of an insatiable curiosity to know the real meanings of things. He wishes to relate the manifold objects of his world and to explain them by referring them to some general law. His mind is capable of assimilating knowledge covering all fields of human activity, but the power of expression often lags behind that of appreciation.

It is a period of emotional contrasts, teachers and school subjects are either hated or adored, there is no room for any middle position. The love of nature and of out of doors may now be awakened for the first time. Mr E. G. Lancaster, who allowed young people to express their own feelings and opinions which he published in a syllabus on "Adolescent Phenomena in Mind and Body," found that of 702 returns, 640 expressed some appreciation or love for nature at this period. "The love of nature," Mr Lancaster says, "in the time of its appearing and the curve representing it, are almost the same as those of the religious emotions. It is really a religious instinct and the child is finding God through nature." Out of the 200 cases taken from the biography of prominent men and women of all classes, 109 are recorded by him as being especially moved by natural phenomena at this age.

Nothing is more characteristic of the young adolescent than his superabundant energy of mind and body. He fairly overflows with life. As Dr Burnham says, "His supreme demand is contact with life. He must be active; and his activity must have relation immediate or prospective with the world about him."

As the will develops, reflex actions are brought under control of the higher centers; inhibition plays an increasingly important part. The volatile activities of childhood are fixed; character emerges as impulse is directed and controlled.

The foregoing are a few of the physical and mental characteristics of the young adolescent. It is with this being, newly made over, with his store of inheritance from the past, which may help to make or mar him for life; with his tempestuous emotions almost the only guide in sailing what is to him an uncharted sea; with his superabundant energy and will to express himself; with his insatiable curiosity and craving to know the true meaning of the life he is to live, that we have to deal in the early years of the high school. The question with which we started is brought home to us again: To what extent do our science courses meet the needs of youth at this period?

Before attempting a partial answer to this question, in the light of what has so far been presented, it must be noted that many questions naturally arise to which at present no satisfactory answer can be given. For example, should boys and girls have the same kind of science training in the high school? To what extent should the principle of periodicity be a controlling factor in the arrangement of high school programs for girls? Should pupils preparing for college have the same kind of science work as those who do not intend to pursue their school education beyond the limits of the high school? To what extent should high school science studies be specialized to meet the requirements of different types of mind? How far should they be specialized to meet vocational demands? These are but a few of the questions with which any discussion of the subject fairly bristles.

We may now proceed to consider in the light of what has already been said, some criticisms which may be applied to our high school science. In an article by Edgar James Swift, Fellow of Clark University, on "Standards of Efficiency in School and in Life" printed in the *Pedagogical Seminary* for March, 1903, the author has brought together facts to show how some eminent men and women have responded to the school test. The list of those who have reached eminence in some domain of human activity, and yet failed in performing school tasks in a satisfactory manner is a long one. Among men famous in science are Linnaeus, Darwin, Sir Isaac Newton, Alexander von Humboldt, John Hunter, Charles Lyell, Cuvier, Sir Humphrey Davy, Huxley, and Priestley. The list could be indefinitely extended. The lack of adjustment between school life and life outside, the author ascribes to a fundamental difference in the way in which children get and interpret intelligence, since his experiments in the psychology of learning seem to show that "the visual, auditory and motor minded only imperfectly share in the experience of one another." This criticism has a bearing on the question as to how far our high school courses should be specialized for different types of mind, but this problem can not detain us at this time.

The same author also criticizes school work as too strongly analytic, and this is of importance to our present discussion. "Life outside of school" he says, "is preeminently synthetic, and failure to recognize this gives force to the claim that the schools are unpractical, and children whose minds are especially synthetic suffer by comparison with those that take naturally to analysis."

Recent statements by prominent teachers of English literature show that they appreciate this danger in their teaching. They protest against the analysis which dissects a masterpiece so that the pupils lose the feeling for the whole work.

In a paper on "Synthetic Nature Study" before the nature study section of this Association at its meeting in 1901, the present writer took occasion to insist on the necessity for a wider recognition of the synthetic principle in education. Mental organization — the power to do work — depends on synthesis of elements. Isolation and analysis are necessary but the emphasis has always been placed on the analytic rather than the synthetic phase in our teaching. Hence the failure of the laboratory method in science, when unaccompanied by discussion of the textbook, the function of which is to relate the more or less isolated data of the laboratory to each other, and to the great body of organized knowledge which we call science. One principle of synthesis for the biological sciences may be found in modern evolutionary views as to organism, function and environment. We have not yet begun to appreciate the full importance of the doctrine of organic evolution as a factor in synthesis. What the principle of the conservation of energy does for physics, binding its elements into an organized body of knowledge, the doctrine of organic evolution does for the life sciences.

The great emotional and intellectual awakening which is so characteristic of early adolescence seems to require that we offer early in the high school, or in the last year of the elementary school, a broad course in general science which shall be intermediate in character between the nature study of the elementary school and the science work of the later years of the high school. The differences conceived to exist between the character and aim of nature study and science have recently been expressed by several teachers in a symposium in the *Nature Study Review*. As Dr Bigelow there says, " Nature study is primarily the simple observational study of objects and processes for the sake of personal acquaintance with the things which appeal to human interest directly, and independently of relations to organized science. Natural science study is the close analytic and synthetic study of natural objects and processes primarily for the sake of knowledge of the general principles which constitute the foundations of modern science." This distinction is valid in a large way, but there is a danger in connection with its application, especially at the period of adolescence — in that it may tend to exclude all organization of material on a scientific basis in the later years of the elementary school, keeping the child too long in the leading strings of a simple observational nature study when he is anxious and able to begin to organize his information on a basis more nearly approaching the scientific. On the other hand its application at this period may encourage too early an insistence on rigid logical analysis and technical scientific methods.

This intermediate general course in science should be based on laboratory and field work by the pupils, and offer every possible opportunity for healthful and organized activity by means of excursions afield, to museum and shop, and by means of manual work at home and in school. It should make a strong appeal to the emotions and to the imagination at the same time that it presents the truths of science. While scientific in the sense of being exact and accurate the course should be predominatingly historic, humanistic, synthetic and evolutionary in character. It should treat of nature in a large way, broad enough in its scope to include some elements of the sciences of astronomy, geology, anthropology, physics, chemistry, botany and zoology. It should teach the elementary facts of personal hygiene. The controlling thought of the course should be the conquest of man over nature, over the material world and its forces, over the plants and animals, and finally, man's conquest of himself; throughout all the course both as an individual and in his social relations.

Such a course should begin with the observation of the apparent, and might well have as a starting point the study of the visible heavens, the phases of the moon, the movements of the planets and the sun, meteors and comets, eclipses of the sun and moon, with simple explanation of the real constitution of the heavenly bodies. This is also the time for sun myths, star myths and moon myths, and all the rich legendary accompaniment which children love. Gradually the geocentric point of view, which is that alike of children and of primitive peoples should give place to the heliocentric standpoint, whence should follow the nebular hypothesis, and the story of the geological history of the planet as it cooled from a nebulous mass to a sphere on which life became possible, and the further story of the development of life on the globe. Laboratory and field study and excursions to museum collections should give this work the necessary objective foundation. If the geography of the elementary school has been of the older type, concerned primarily with topography and the political relations of peoples, it would be well to include here some simple observational work in physiography, the character of the work depending on the opportunities the home region offers. The work of geological forces is still going on, and evidences of former activity are everywhere available, but in lieu of the real objects and in addition to them, pictures, lantern slides, stereographs, selected series of fossils, and models of physiographic structures should be utilized. The story of man's evolution from a prehistoric savage ancestry should be told in this connection, illustrated by the largest possible use of anthropological material. In physics and chemistry the topics should be presented with laboratory experiment, but in historical perspective, and with constant reference to biography. Time is lacking today for the further development of this course. It has been given at the Ethical Culture School for the past 10 years to children of the eighth grade — the last year of the elementary school.

Whether or not a general course in science such as that already outlined in part, be offered in the last year of the elementary school, or the first year in the high school there is the further problem as to the sequence of the special sciences in the high school. There is as yet no uniformity in the order in which the science courses are offered. Botany, physiology, physics, chemistry and zoology are the sciences most often chosen, in a smaller number of cases physical geography is given. Astronomy and geology are usually left to the college. Physiology is very generally given a place in the first or second year. In the East the biological sciences are more generally given early in the course, in the West they are usually offered later. It has been stated by some that the interest in living things is likely to be greater in the early teens than later. Some have preferred to place physics late in the course on account of the mathematics involved. The writer believes that there is danger of losing the psychological moment for the nascent period of interest in living things if physics or chemistry precede the organic sciences in the high school course.

If the biological sciences are placed in the first or second year of the high school, it would seem from what has been said of the nature of adolescents that there were strong arguments in favor of a single course in biology, as against a year of either botany or zoology; and in favor of including in this course some work in human physiology. The latter subject has always had an anomalous position in the high school. Though usually offered as a first year subject, it can not be presented at that time with the preparatory biological work which gives it meaning and perspective. The effort of teachers of physiology today to give the subject an objective basis in laboratory work is to be commended, but if it is approached after some study of the plants and lower animals, it gets a new meaning and interest. In this way the most important physiological principles having been studied in their simpler manifestations, and a great body of morphology being available to help in understanding the structure of the most complex of all organisms, most of the time of this part of the course can be given to the subject of hygiene.

And now a word as to the content of biological courses in the high school. Observation in the classroom, examination of the printed outlines of courses and discussion with teachers seem to show that the emphasis is still too strongly placed on the physiological and morphological, to the exclusion of the practical and economic relations of the subject. It is comparatively easy to build up a knowledge of the life sciences with the modern laboratory facilities. The danger is that this structure reared will be founded merely on the laboratory, and thus fail of contact with nature, or with vital human interests in the outside world. The laboratory is a means to an end. In our effort to build up a scientific body of knowledge, we should see that it does not fail to touch life as closely as possible, and be in some measure a preparation for that larger life of the world outside of the laboratory walls. There should be a garden and conservatory in connection with every botanical laboratory, as there should be a vivarium accessible to every high school student of zoology. Here every opportunity should be offered the pupil to experiment and to observe phenomena which are directly related to human activity. I am well aware that this savors of a counsel of perfection but I believe that the demand will be justified in the fulness of time.

President Hall, in his "Adolescence," from which we have already quoted, takes teachers of science to task for violating "the basal law of psychic growth" in the exact, technical, logical way in which the sciences are taught. He thinks "the modern pedagogy of science is threatened with a singular alienation from the love of nature," illustrated in the use of technical nomenclature, in the too early use of mathematics, and in the overemphasis on morphology. There should be, he says, "a humanistic propaedeutic, because growth in the adolescent period is in the humanistic stage. Love and enthusiasm for nature, if it is ever to arise, is now in order. Nature is sentiment before it becomes idea, or formula or utility." He says specifically of high school teachers of biology that they have singularly lost contact with the nature and needs of childhood and growth.

Prof. E. G. Conklin, of the University of Pennsylvania, in a recent lecture before the New York Association of Biology Teachers, criticized the emphasis placed on morphology by teachers of biology. "They seem," he said, "to have forgotten the definition of the word biology, as the science has to do with living things, and make of it the study of the dead bodies of animals and plants."

Evidence is accumulating that a great change is now being effected toward a broader biology teaching, and with a fuller knowledge of the nature of adolescence other changes are sure to follow, especially in the direction of humanizing the science, so that from it shall be struck the sparks that will glow in later life with passion for the great world of out of doors and help to bring men truly back to a love for nature.

Only brief mention can be made of the inorganic sciences. It seems to the writer that the earth sciences, geology and physiography, belong to a later stage of development than the life sciences, except in the elementary way in which part of their field can be opened to young pupils in the general science course already outlined. This seems to be true when the native interest in the phenomena concerned is considered, and it seems true when we think of the character of the laboratory and field work which these sciences can offer to young students, and the relative maturity of mind required to relate the facts of these bodies of knowledge. Certainly with the pressure of many subjects in the high school there is need of condensation and even elimination. The claims of both physics and chemistry are valid; it would be most unfortunate if either of these were crowded out of the high school. One general criticism of these subjects is the same as has already been made with reference to work in the life sciences — that it would seem that both physics and chemistry ought to be able to make a more definite contribution to the needs of life after the school period. Mr E. C. Whitman in an unpublished paper has offered some suggestions for what he called a course in "domestic chemistry." It might be well for teachers of chemistry to consider how far some of the more important of these topics could be incorporated into a course in general chemistry, tending to give it a more practical application to life. Some of the topics he suggests for study are as follows:

Hygienic care of the house cleaning; dangers from dust; sweeping and dusting; use of oil on floors
Cleansing
  Removal of ink and grease spots, fruit stains, paint
Bleaching and dyeing
House drains, sewers
Disinfection and fumigation
Chemicals for emergencies. Poisons
Drinking water. Sources of pollution
  Methods of purifying water
Foods
  Classification of the chemical constituents of foods and study of typical compounds in each group
  Chemistry of digestion. The action of enzymes
  Nutritive values and cost of food
  Methods of canning fruit and vegetables
  Dangers from bacteria, souring, decay, development of ptomaines. The refrigerator, pure ice
Adulteration of foods, coloring, preservatives
  Fermentation, yeasts, vinegar
  Chemical analysis of baking powders
  Chemistry of bread making
Proprietary medicine frauds
Study of the laws relating to pure food, and laws needed for protection of the consumer
The sanitary condition of the city

My attention was drawn to the question with which we have been concerned this afternoon after several years' experience in teaching nature study to kindergarten normal training classes composed of girl graduates of the high schools of New York city and vicinity. I had often been surprised at the apparent ignorance of many of these pupils of the simplest phenomena of everyday life, even after they had taken several different science courses in the high school. And what seems far more important, I could not see that there was any vital interest in nature on which to build. I then began to consider why the high school science work should not have made a more definite impression on the minds of the pupils.

In order to get some idea of the pupils' own views as to the value of their high school work in science the following questions were put to the pupils in this year's junior and senior classes of an average age of 19 and 20 years respectively.

What science work did you have in the high school? Describe briefly the character of that work.

Were you deeply interested in the work at the time? Why? Are you still interested in the same subject or subjects?

Do you now feel that the work was of value in fitting you for further study, especially of science? If so, in what way primarily? On account of the information gained, the habits of study and thought formed, or in the interest aroused?

Time is wanting this afternoon for a detailed analysis of the returns. In general it may be said that nearly all the pupils expressed themselves as much interested in the work at the time, and nearly as large a number said their interest had continued to the present time. Nearly all said that the work had been helpful, the majority counting as most valuable the interest aroused and the information gained.

It must be confessed that the returns were a surprise in view of the large number who felt that they were deeply interested in the study of nature, and had profited at least to the extent of having gained some information on the subjects studied. It then occurred to me to attempt to test this knowledge, and the following request was made of the classes at a subsequent time:

Write a short essay on any science subject which you studied in the high school, and which you think you understand today.

The results obtained from this series of papers bore out the general impression already formed of the pupils — that there was in reality very little accurate knowledge of some of the simplest science subjects. They can hardly be considered to be vitally interested since they are not, as a rule, carrying on any independent observations, or study of nature.

From an experience with these pupils covering a period of over fifteen years, and especially from returns which have come to me from the pupils after they have gone out to teach, I am convinced that the most precious result of nature work with adolescent pupils is emotional, rather than intellectual. The windows of the soul never open as widely on nature as in those days when the first flush of the new spring of life is felt in the early teens. If the psychological moment to arouse and develop an interest in and love for nature is lost, the child grows up emotionally atrophied, and intellectually dwarfed. He is hopelessly crippled in power to make any independent observations, or to reason about natural phenomena, for he lacks the motive power which moves the man of science. We observe and study the things we care for, and because we care for them. There is no such thing as training a faculty of observation and power of reasoning when feeling does not supply a motive power.

It is not so much the purpose of this paper to criticize the science work of high schools, as to bring the question before thinking teachers. In how far does our work in science meet the highest needs of our pupils? In order to answer the question science teaching must be grounded in a knowledge of the nature of the pupils we are aiming to instruct. It is full time that it is recognized that there are problems for the high school teacher of science to investigate in the classes which pass before him, and that it should at least be expected of the teacher that he know as much of the instinctive reactions of *homo sapiens juvenis,* as of *Amoeba proteus.*

It is only when this knowledge is generally available that the science work of the high school can be of its greatest service to the soul of youth in the upbuilding of character, in the sense in which Emerson uses the word. "Character denotes habitual self-possession, habitual regard to interior and constitutional motives, a balance not to be overset, or easily disturbed by outward events and opinions, and by implication points to the source of right motive."

SECTION MEETINGS

Wednesday afternoon, December 26

Section A — PHYSICS AND CHEMISTRY

MORE INTERESTING AND PRACTICAL MECHANICS FOR THE HIGH SCHOOL

(Abstract)

BY J. M. JAMESON, PRATT INSTITUTE, BROOKLYN

The man who, in these days, is to take his proper place in the community in which he lives, who is to be a producer and giver as well as a consumer and receiver, must be familiar with the larger principles of mechanics. The number of mechanical appliances in common daily use is multiplying with almost incredible rapidity; automatic machinery with its resulting rapidity and cheapness of output is everywhere replacing hand labor in manufacturing establishments; facilities for transportation and communication are being developed in even the smallest villages; new bridges, subways, public buildings, etc. are everywhere in process of design or construction. Our business and professional men, our public officials, in fact our men of affairs of whatever kind are constantly placed in situations which demand from them industrial and mechanical intelligence.

We rely upon our public schools for the education of the great body of our people. Hence it immediately becomes a pertinent question: What are our public schools and particularly our high schools doing to develop industrial and mechanical intelligence?

Now I do not wish to be understood as suggesting that our high schools should provide instruction in the particular activities in which its graduates are likely to engage. Such instruction might produce a few skilled artisans; it would hardly develop broad intelligence. I am not suggesting trade courses or even technical instruction. But I do feel that our high school courses and — since that is the subject with which we are immediately concerned—that our high school course in physics in particular, should be suited to the needs of the pupils; that it should connect immediately and in no uncertain, half defined way, with life problems; that it should furnish a broad and really intelligent grasp of such fundamental practical ideas as the principles governing the distribution of forces in structures, the transmission, transformation, and utilization of energy together with the conditions which control the losses during such processes; and above all, that it should provide such opportunities for experimenting with real problems in an actual way as shall develop the point of view and resourcefulness necessary to meet successfully the rapidly changing conditions characteristic of the age. The days of apprenticeship are past, for the system is too slow for modern progress. Before the period of the apprenticeship is completed, the methods learned are out of date. The need is, nowadays, for quick, resourceful, broadly trained minds which are capable of rapid development along several lines.

Physics is admirably adapted by the nature of its subject-matter to be one of the most effective agents in providing the type of training just suggested. It may be used for the purpose without sacrificing in any way the cultivation of judgment, of regard for truth, of precision, and of those other intellectual and moral qualities for which the physics teacher strives and in the capacity for which he believes his subject to be rich almost beyond comparison. And yet we must admit that physics teaching as now generally conducted in our high schools, is not contributing greatly to this end. Several reasons in my judgment may be advanced for this failure, foremost among which should be mentioned the neglect on the part of so many teachers of physics to provide proper instruction in mechanics.

During the past five years, several hundred physics laboratory notebooks submitted to the College Entrance Examinations Board from all sections of the country have passed through my hands. These books are always better evidence of the teacher's conception of his physics laboratory work, of the ideals he has created and of the spirit he has succeeded in arousing than they are of the mental equipment of the pupils. The most striking general conclusion which they seem to point is what may be termed the too general indifference of physics teachers toward the subject of mechanics.

Under the very broad provisions of the Examinations Board regarding the distribution of the laboratory exercises among the subdivisions of physics, mechanics is frequently minimized to provide more time for light or sound. Not infrequently the entire laboratory work in this subject is represented by three or four exercises in measurements — such as the distance between two fixed points, the dimensions of a block, or the diameter of a cylinder or sphere, six or seven exercises in determining specific gravity; an illustration of the parallelogram of forces, and Boyle's law. There is nowhere any evidence of an attempt to show the application of the two last mentioned.

Those books which indicate greater time spent on mechanics represent an attempt to cover a larger proportion of the work now laid down in one of the several lists of laboratory exercises regarded as suitable for secondary schools rather than any serious attempt on the part of the teacher to so modify the character of the teaching as to make this subject really useful either for information or for training. In none of them is there evidence of an endeavor to keep pace with the changes in the interests of pupils, to recognize the different surroundings which now control their lives, or to provide for the practical problems which they are preparing to meet. The average index of exercises in mechanics differs in no essential respects from the original list which appeared in that now ancient classic—"The Report of the Committee of Ten."

Again the emphasis placed upon the several subdivisions of mechanics is not properly distributed. The time available for physics in the high school is necessarily short, and in teaching mechanics, therefore, the great principles which are far-reaching in their applications, should be emphasized and the relatively unimportant portions passed over lightly. Under such circumstances, what could be more absurd than a selection of laboratory exercises which, out of a total of 29 possible exercises in mechanics gives 8 or nearly 30% of them to specific gravity, 4 or over 14% to special levers, 6 or nearly 21% to the technical subject of the properites of materials as against 7% to forces other than parallel, and none whatever to the laws of rotating bodies, or to the great principle of energy transfer, work, efficiency, and conservation of energy?

Then also too much time is spent in the presentation of mechanics, dawdling over trivial and obvious facts. We should credit our pupils with a reasonable amount of common sense and an ability to "rise to the occasion" if required. Propositions which, when fairly presented, are grasped at once in all essential details, do not require demonstration. For example, what pupil needs actual experimental proof that the upward reaction at the fulcrum of a lever is equal to the sum of all forces downward? Or to carry through separate exercises on the effect of the weight of a lever, or on each case of the artificial classification into levers of the first, second, or third class? To be sure these things may be so fogged in a haze of directions that both pupil and teacher are worried. But the difficulty here arises not from the fact that the mechanics is too hard but because attention is focused upon carrying out a set, rigid procedure without slip or omission. All *actual* levers have weight; *all* obey the common law of moments. Teach the pupil what is meant by moment of force and by moment arm; show him how to pick out the moment arm with respect to a given axis; put the whole case fairly before him and let him use some initiative. In nearly every instance he will readily find his own way, and will see for himself that the weights of the parts of structures always come in as additional forces with moments which must not be omitted, and that certain general conditions must always be met in any arrangement of forces.

The method here suggested of taking problems in the large and allowing for special conditions as they arise without separate demonstration is of the utmost importance to the teaching of mechanics. In the first place it concentrates attention on main principles and crowds special details into the background where they properly belong. It cultivates resourcefulness. And finally it saves time so that exercises of real practical value may be introduced, which shall arouse the pupil's interest and directly connect his study of mechanics with the problems and appliances of his daily life.

Finally, and perhaps I ought to say, *chiefly*, mechanics teaching is not now accomplishing its legitimate share in the training of high school pupils because we teachers fail so frequently to intimately connect the classroom and laboratory work with the daily experiences and interests of the pupils. All young people are interested in explanations of large enterprises; in things that "go" and things that "do." But our laboratory apparatus illustrates academic conditions and fails to suggest the possibility of practical applications. Our pupils therefore soon fall into the habit of regarding their mechanics much as they do certain other subjects in the school curriculum, as a thing to be endured rather than enjoyed, to be passed with credit if possible, but under no circumstances as anything which exists other than in the abstract to be always shut in by the classroom or laboratory door.

Now what should be done to put the mechanics teaching "in phase" with the conditions of the day so that it may become as it properly should, a valuable agent in high school education? I am hoping much from the so called "new movement among physics teachers." It is a question, too, which in my opinion this organization might well take up. But whatever the source of the movement, two things must be accomplished: many teachers must be roused to a better conception of the aims and possibilities of mechanics teaching; and sweeping changes must be effected in subject-matter and in the manner of presentation. Toward this movement I wish to offer the following suggestions:

1 That all formal exercises in measurements of lengths, diameters etc. should be omitted, and such measurements taken only as required for the purposes of some actual experiment. Only when done in this way as a means to a clearly defined end do they possess value or interest.

2 That the laboratory exercises in specific gravity determinations and allied ideas be not more than two in number. These should establish the principle of the buoyant force of liquids and fix the idea of the term specific gravity. Any loss which seems to be incurred through this reduction in the number of such exercises will be more than repaid by the exercises which replace them.

3 That time be economized through a better grouping of the facts of mechanics. For example, all the somewhat scattered ideas of statics may be grouped around the central idea that the forces acting must produce no change in the existing condition of motion of the body acted upon. It follows therefore that the forces in any given direction must always be balanced by equal forces in the opposite direction; and that any tendency which the forces may have to produce rotation in one direction must be counteracted by an equal moment in the opposite direction. In other words we have the general conditions for equilibrium in a plane that the sum of the X forces, the sum of the Y forces, and the sum of the moments must each be zero. This is a central idea that sooner or later in his study every pupil should obtain. The parallelogram law, parallel forces, and nonconcurrent forces may then all be reviewed as special arrangements of forces, coming under these general conditions.

Again the idea that action and reaction are always equal and opposite is a convenient starting point for teaching not only statics but also dynamics where inertia reactions must be considered.

4 That instruction be given in the dynamics of rotating bodies. This is too important and too general an idea to be omitted as is now generally done. The laws of rotational acceleration, and of the relations of moment of force, rotational inertia and angular acceleration should be taught at least in their general aspects, as well as the corresponding cases of motion of translation. Such topics as the stored energy of the rotating parts of a machine, energy relations in starting and stopping machinery, etc., should also be discussed.

5 That the general laws of statics discussed in the classroom and lecture periods, should be applied in the laboratory through a study of models of structures which reproduce as nearly as possible the conditions of actual practice. These models may be readily con-

structed at small cost and should always be large enough to suggest possibilities of actual use as then only will they command respect and arouse interest. Various forms of trusses, derricks, cranes, arches etc. may be suggested as suitable subjects for models. And here it should be said that it is not necessary and indeed not often desirable that there be duplicates enough for all members of a section to be doing the same thing at the same time, or that any pupil should work experimentally with all models. The ideas are sufficiently similar so that no confusion need arise, and much value may be obtained through discussions, before the class, of the results obtained by different observers. Again it is not necessary that a student make a complete study of a given model. The need in secondary instruction is not for precise knowledge of theory, but rather of the thing itself; what it means, what it does, what are its effects and applications. Hence a number of studies may be made of each model, each one designed to find out one definite point. In this way the work may be made as easy or as difficult as desired and may be made to fit in with any schedule of laboratory time.

6 That each student be provided opportunity to study the transmission and utilization of energy, to trace and measure the loss in all these processes and to study ways of reducing such losses. The facilities for this study will depend greatly upon the equipment and power supply of the school. In any case, it is not difficult to provide various small gear, belt, and sprocket machines which may be operated by means of cords passing around drums attached to the shafts and supporting scale pans. The sprocket wheels of an old bicycle which may be obtained at small cost from any junk shop provides apparatus for several excellent exercises. These small machines should always be made up from commercial parts and should not be fitted too freely with special ball-bearing or friction-reducing devices. They should be large enough for some actual service. Let the pupil deal with the conditions which obtain in practice. The one experiment of this sort most often used, that of the efficiency test of a system of pulleys, done as it usually is with an 8 ounce balance and special cone-bearing pulleys giving an efficiency that is absurdly high seems to me in these days to be almost if not quite worse than nothing. If the experiment is done let it be with a ½ inch rope, a heavy weight and the pulley sheaves of common use.

Where the equipment of the school will permit, also this line of study may be extended to a study of speeds and friction of shafting, the general details of the school power plant, efficiency tests of electric and water motors, etc. The teacher should not feel, however, that this larger equipment is absolutely essential to good instruction in the sort of mechanics here suggested. Excellent results may be obtained with the small devices mentioned above which are surely available for every laboratory.

[In conclusion, to illustrate the type of instruction suggested as needed, the speaker exhibited lantern slides showing models of a simple truss, roof truss, crane, and arch now in use at Pratt Institute, also of a screw jack arranged for an efficiency test, and of an apparatus for studying rotary motion, and the kinetic energy of a rotating body.]

Section B — BIOLOGY

BIOLOGY AS METHOD AND AS A SCIENCE IN SECONDARY SCHOOLS

BY HENRY R. LINVILLE, DE WITT CLINTON HIGH SCHOOL, NEW YORK CITY

Not an uncommon criticism on the results of school as well as college teaching of biology is that our much vaunted scientific method does not show any appreciable effect on the minds of those who devote themselves to biology for even a considerable length of time. I have heard it maintained by skeptics that, for example, botany and logic have nothing to do with one another, so obvious is it to them that a man may be a good botanist and not a logician. It would seem that a botanist or a zoologist might carry through even a work of investigation arriving at apparently sound conclusions, retaining thereafter scarcely a trace of the impress which the employment of the logical method of thinking should have left upon his mentality.

Another important criticism on the results of our teaching frequently made by those who are not biologists at all, is that the apparent subject-matter of an ordinary course in botany or zoology consists of a congeries of facts more or less closely related among themselves, but having no evident connection with the life of man. To these critics it seems that biologists as a class contribute little or nothing out of their store of knowledge to the solution of the manifold problems of human life. Do scientific biologists contribute no more to the progress of human society than, for example, the scientific philologists?

Before considering these two criticisms, it seems to me sound that ultimately no branch of science or learning of any kind can stand in our educational programs, unless it is able to meet philosophical criticism from every source. The more we biologists stand together establishing a little realm of thinking, or lack of it, to ourselves, the greater will be the fall when it comes. When in these days of highly trained professional biologists, many of us sneer at the essays of sociologists in our field, we forget that many men who were not biologists primarily, from Aristotle to Spencer, have made substantial contributions to our store of knowledge and to our philosophy. And so, when thinkers along general lines say that biology as it is taught does not train to thinking, it may pay us to halt and consider the matter.

There is a large class of biologists that the question in its large relations does not touch at all. Most of the colleges support biologists who have no particular interest in the relation of biology to any other matter. Those of us who are on the inside know that a high percentage of the work published as researches is done by men whose chief ability lies in the direction of discovering facts that others have been too busy to look after themselves. The most ordinary power will enable them to tack these facts on to theories already formulated, and fairly established. As to thinking beyond the reaches of what is called "common sense," there may have been none. Another group of biologists content with their ability to break out new lines of scientific endeavor, have scant sympathy with movements which have for their purpose the use of the subject-matter of biology for general educational purposes. But whether he will or no, the days of the pure scientist are drawing to a close. The leader in pure science can not be a leader of the people, unless he does something to relate his work to human progress.

If we concede that human progress in all its phases is the most important thing that can take place on earth, then it becomes appropriate to ask if any tangible force can be named which has been instrumental in attaining the end toward which we are moving. It is just as obvious that the ideas of men have given the impetus for all advances in civilization, as it is that the thinking power of the brain has produced those ideas. In the conflict of ideas worked out by the brains of all the races, those ideas which by reason of the appeal they have made to the developing conscience of mankind, have gained the ascendency. The strongest ideas as held by the several contemporaneous and successive civilizations have existed as the result of the collective thinking of all the brains, although the expression of the ideas we may rightly credit to those leaders of thought who were able to formulate them. Now, we are accustomed to measure the civilization of the various nations by several criteria, such as intellectual, esthetic, moral, social and industrial development. The respect with which man regards development in any of these lines depends in a certain measure on his own mental environment, but even in our own country whose industrial development leads all others the elemental necessity of the ability to think must appeal to every one.

I believe no teacher would question the statement that much, if not most, of our teaching in the schools consists in disseminating information. Superintendents of instruction as a class fight against the introduction of any element, called scientific, that is supposed to render difficult the getting of information by the children. It is true that some subjects are supposed to provide mental drill, but what kind of mental drill do we mean? Most apparently the ability to remember. The proof of it is to be observed in our examination system, which for the most part is a test of the memory, and seldom of the ability to think. So insistent are the controlling boards becoming, that a reproduction of the marvelous memories of educated Chinese would seem to be the logical outcome of western education. If this is to be the result, many of us will feel in entire sympathy with the expression of Themistocles, quoted by Matthew Arnold, "Teach me rather to forget!" As Matthew Arnold continues, "The sarcasm well criticizes the fatal want of proportion between what we put into our minds and their real needs and powers."

For some years, physiologists have been trying to discover what the "real needs and powers" of man are in regard to his food. Without doubt, a similar desire is at the bottom of the most valuable studies of our educational method. It seems to me that from the point of view of the good of all the people, the most basic need is the development of an organic power to think. I believe it could be demonstrated to those who have the power to think abstractly, that all of the injustice that is included in the phrase "man's inhumanity to man," could be stopped if the people could be stirred to break from their dependence on hidebound tradition and authority. If real self-reliance in our thinking is a primal need and of great value; and if our heritage of information that the books contain may be stored in imperishable buildings, rather than in perishable brains, then the sooner we enter upon a new era, the better.

There is a general impression among teachers that children do not begin to reason before they reach the high school age. And in the high school we hear the opinion that certain subjects should be taught for the information they contain, the presumption being that no thinking — only remembering — will be required. It is true that those children who enter the high schools today are not, as a rule, able to think abstractly. It is also true that those parents and teachers who treat the minds of their children with respect, are able to see intellectual growth through the habit of leading them to understand the reason of things. We have never heard of any scientific study which proves that children develop the reasoning faculty at a certain period, as they develop permanent teeth. It is rather more likely that people have repressed the natural reasoning faculty in children by requiring them to believe as they believed — because some dominant personality said so.

Much as I believe in biology as an instrument of good in educating the people, I regard the dissemination of information concerning plants and animals as the least important of its uses; but for the most part, that is all we do. We fill up with all the pupils can hold, mostly because we do not know what else to do. We try to make the subject interesting, because we want them to be pleased with it. We sometimes avoid the hard places for fear the interest will lag. We pay tribute to the little gods and goddesses by giving out predigested mental food, but we have made them mental dyspeptics. They are not that way naturally.

If we as teachers were not carried along by the tremendous impetus which the present system of education has gained, much as the individual pedestrian in Broadway is rushed along by the crowd behind him, more of us would have time to at least stop and think whither it is all leading. If such an opportunity were offered, I believe we might agree that one desirable object would be that we should have such a handling of subject-matter as would lead the children to consider the facts they learn in relation to other congeries of facts; in other words, to interpret nature. For example, the idea of a tree would not be a dozen or more kinds of trees, and nothing more, but the tree as an organic thing would be explained or interpreted through the consideration of the seedling, the soil and water, and the air. At the other end of the story the meaning of the tree would be interpreted in terms of its relations to other plants whose existence is interfered with or favored by it; in relation to animals that use it for food or protection; in terms of the water supply for cities; and in terms of materials for the use of man. This is not a new idea. We all know how poor an imitation of a scientist is the person who "knows all the plants," but I doubt if we keep before us the importance of the thinking idea as training in method. While knowing the dozen or more species of trees on the mountain may be but a feat of the memory, the knowledge of one tree or plant of other kind as an organism must come through the serious consideration of the relation of things. This process requires continual thinking. It is as much the logical process as anything can be, when in experimentation to determine the relation of moisture, heat, air and light to germination and growth, the pupil is encouraged to analyze, eliminate, control factors, and to reason from results. The method of learning the principles of biology by experimentation is the scientific method. Those who criticize our work because it does not show in its followers the discriminating habit of the logical mind are in effect attacking our practice of verification. I have had the opportunity lately of examining the laboratory questions used in an elementary course in zoology in one of our foremost universities. The questions were nothing but statements, which the students were asked to verify. The students have no opportunity to discover for themselves the facts in regard to the form and activities of the Paramoeium, through the exercise of their powers of observation, mental analysis, elimination and judgment. On the contrary, they are being robbed of a splendid opportunity to develop those powers, and to gain through their exercise intellectual pleasure of high quality.

I maintain that the consideration of the logical relations of the science of biology, and the employment of the logical method of thinking in full or abbreviated form in learning the science, are of more than incidental importance. If there is any value at all in education, it comes through the additional power gained to the individual and to society. If civilization advances through the power of great ideas evolved by growing society and formulated by our leaders, then whatever help the education of the schools can lend to the evolution of ideas, society will be by that much the gainer. The greatest use that I could wish for the science of biology is that the practice of its method should promote the habit of thinking in men, and be of indirect use in suggesting, receiving and judging ideas of all sorts developed in the progress of the race.

There is a distinction to be made between the method of a science and the substance of the science in relation to the bearing that both have on education. The method is a logical system which may be abstracted from all relation to subject-matter, and serve an important intellectual end in developing the power of independent thinking. The science of biology must have educational value beyond its value as method; otherwise, it would be difficult to justify its inclusion in educational programs.

The unified body of knowledge which we sometimes designate by the term "the science of living things" comes into the closest imaginable relation with ourselves as men. Some one has borrowed from biology an idea and applied it in this form: Education is adaptation to environment. I think that it can not be doubted that the scientific understanding of organic environment, by its comprehensiveness, its fulness and its characteristic of exhibiting things in their natural interrelation tends to give the student the knowledge whereby he can see himself in a setting, so to speak. Instead of thinking of himself as an isolated creature, or at most, his race as an isolated race, he is educated to think of his race in relation to all organic factors that affect the race. Whether the student formulates his feeling or not, his intellectual life has the added balance and sureness which is evident in the thing we call power.

It is true that the young student of biology as he has been trained in the past could not attain to the largeness of view at which I have hinted, in the course of a few brief weeks, for the reason that the teaching of the science is yet in the experimental stage. Undoubtedly, we waste a great deal of time in busying ourselves and our students with looking at things without thinking much about them; and as the volume of known facts increases, the impossibility of passing them all in review becomes more and more apparent. We shall be driven to the necessity of concentrating our pedagogical energy, first on devising a scheme by which the method of biology shall be more immediately effective, and then to the task of so organizing the typical facts that the principles of the science may be got hold of in much less time than is now taken by the special student of biology.

It is apparent that before the knowledge of biology as a science can become general, we must save in time and we must also have more time. The need of this knowledge has never seemed so imperative as now. The imminent social revolution in the civilized world is being hastened by the ideas of the new science of sociology. Practically none of the professional sociologists have a working knowledge of biology, yet they are constantly basing their theories on biological phenomena which they know little about. Granting that the object of the sociologists is the betterment of the human race, their lack of ideal power through ignorance of the application of biological theories, is all the more unfortunate. The sociologists realize their lack of efficiency; but they can not get much work done as sociologists, if they are obliged to spend years as students of biology. I think the only way to help them and the people generally is by the system of teaching that I have suggested, and by closer knit and more effective organization of the subject-matter for presentation.

When the bearing of evolution, the most important principle of biology, on human affairs is fully comprehended by educated men, and the influence of the selective factor in hastening the process of evolution is realized, we may hope to see curricula contain a maximum of subjects that relate to human progress and a minimum of those that stand in the relation of organs that mark the progress of evolution, but hold slight promise of usefulness for the future. The process of natural selection, and even of intelligent selection, involves the retention of undesired characters. This fact helps us to understand how it is that certain unused languages are still retained in our courses of study, but it offers no excuse for giving more time to one of those languages than we do to any other subject.

Very great stress continues to be laid on the importance of Latin and other "humanities" for their mental discipline and culture value. The implication has been that science does not hold as much mental discipline, and of course does not tend to culture, being materialistic and not idealistic. It is not apparent, however, that the study of Latin yields training much above that which a student would gain from the performance of any series of well ordered tasks. He is taught to remember, and he is taught to be careful, but I can not recall any bit of thinking in the study of Latin which I did that has been of service to me in any other relation of life. It is true there is said to be a logic of grammar, but is the logic of Latin grammar essentially different from the logic of English grammar, and is that what the defenders of Latin spend four years in teaching in secondary schools?

The further claim of culture value in Latin and the "humanities" has lost much of its force since some of those who believe in it have begun to include the sciences in the humanities. But there is hardly any question that most of those teachers would claim greater cultural value for the ancient languages, as against the modern sciences. The term culture as at present employed is so inexact a symbol that it is impossible to measure values with reference to it. If culture means the education the scholars got when little but Latin was taught, then I think we have done with it. If it means the state of enlightenment which some regard as ideal for civilized men, enlightenment with reference to what the world is, and to man in his multifarious relations, then not only is knowledge of the sciences necessary, but knowledge of history, literature and art also. It is evident that only through such enlightenment are men put in touch with their environment. When they are in touch with their environment, they have the feeling of acquaintance and power which enables them to be factors in the further extension of human progress.

It is probable that to some people culture means a sort of delicate refinement of knowledge in the line of classical literature and art, extending in some cases to modern literature and art. Of course we understand that the professional ancestors of these scholars were the first to own the word, and for a long time they could make it mean what they pleased. Every school and college holds some of this kind of citizen resenting bitterly the gradual withdrawal about them of allegiance to the past. Many of them see only gross commercialism in the sciences, and the loss of idealism. But while they are spending their breath, the evidence of man's relation to the organic and the inorganic world is becoming overwhelming. The grander idealism portrayed in the effort to come into exact relation with the world and its work through knowledge, makes the ideal of the classicist seem paltry in the extreme.

I have discussed the method of biology, secondly the bearing of the science on the individual in his relation to society, and third, the bearing of science in general on culture. I shall now say what I can on the esthetic value of biology.

It has not been many years since the artists generally would say that it was impossible to formulate the reasons for considering one picture better than another. The conviction regarding superiority seemed to rest in the emotions, or possibly in the artistic judgment, which appeared to be a different thing from scientific judgment. Now however, we find many teachers of art who believe that the formulation of principles can extend much further than drawing, and that the principles of composition and color relation can be so refined and scientific as to get a tangible basis for a given esthetic feeling. In biology, within the past 10 years much has been written to the effect that in teaching nature study our object should be to stimulate the love of nature, and to help to the appreciation of its beauty. I think that in proportion as we can do this, we shall be accomplishing a splendid work, but the end must not be considered as an end possible immediately, for just as the artist must study anatomy and the principles of composition, so the student of biology must have a good store of facts and meanings. Moreover, in our present state of progress our talk about "the love of the beautiful in nature" is composed mostly of empty sounds. The phrase "going back to nature" expresses little more than an economic and social revolt against life in the cities. Children who are taken to the country every summer are not necessarily taught the beauty of nature, any more than are the country children who stay there all the time. And city and country children are not likely to agree on the beauty of a given place or object, unless there is something in the education of both that leads them to see what it is that makes things beautiful. In other words, we must get at the principles of beauty. The education of the present day farmer is responsible for an expression I once heard when a splendid pine tree was rent by lightning: "What a shame, that tree was worth $5." To our botanist the tree would have been Pinus strobus. For the artist only would it have possessed the quality of beauty, in the sweep of its long dark branches against the sky.

The modern artists have borrowed from us the idea of basing their art on scientific principles, and thereby they are able to teach those who are not artists by nature. Through the influence of the Japanese, they are also making more and more use of animal and plant subjects in their decorative art. Can we as biologists hope ever to teach the beautiful unless we form an alliance with teachers of art? The idea that zoology is associated with ugliness is not altogether unfounded. We must seek to portray animals and plants in their beautiful as well as in their accurate relations.

In the relation I have suggested for artists and biologists, we get a glimpse of the possible benefit of cooperation of all branches of learning. Doubtless there are uses for all the subjects now taught in the schools. If they are to be made effective, they must be taught in cooperation in order to attain an end higher than any subject could reach unaided. In establishing closer relation between subjects, I would maintain that we must employ some criterion for estimating the importance of the various lines of study, and that the criterion be the value of the subject for contributing to human progress.

The criticisms that will continue to be made against biology as a factor in education while the teaching of the science is in the experimental stage, should stimulate us to search for the reasons for our professional existence. The philosophical considerations which have to do with biology and education are of course more fundamental than the expediencies of secondary school courses of study. Although the decisions of the hour may seem to help or hinder the establishment of biology and other sciences in the schools, they should have but slight influence upon a future ideal system of interrelated knowledge for the education of the people.

Section C — EARTH SCIENCE

FIELD WORK IN PHYSICAL GEOGRAPHY

BY JENNIE T. MARTIN, CENTRAL HIGH SCHOOL, BUFFALO

There is no need here to consider the importance of field work in physical geography, as its value is recognized by every one who teaches the subject. I shall try instead to outline for discussion by the section, some of the problems connected with the work while presenting plans and methods carried out in my own classes. These plans have gradually developed during a series of years, and are still changing through the constant effort to overcome obstacles and obtain better results.

There are two important aims to keep before one in this work, first to make it so enjoyable that a lifelong impulse toward the study of nature in her great out of doors laboratory shall be gained, and second to make it so effective that it shall minister directly in the mental development of the pupil.

There are many difficulties to contend with, specially in city schools, the large number of pupils to be looked after, the long distances often necessary to cover in order to reach points of interest, the expense involved, the weather, and greatest of all the inability of pupils to use their eyes or to understand the meaning of what they see. One of the greatest benefits coming from field work I find to be a dawning consciousness on the part of the pupil that he may discover facts for himself and that facts so learned are as authoritative as those he finds in books. It is very difficult at first to get pupils to rely on themselves and to depend on their own conclusions. They try hard to get me to answer their questions for them. With their directions in hand as we pass from point to point they repeatedly ask "What are we to see here?" Finally however the reiterated hint to "Look at your notes" and the patient use of the Socratic method, with now and then a little direct help, makes them somewhat self-reliant and a great victory is won.

In planning excursions I have worked mainly to make them effective believing that this in itself will bring pleasure.

For the early excursions, detailed directions and definite questions seem necessary. But in using them I have found on the part of pupils a tendency to be satisfied when they have made the required observations, so that they do not see much for themselves. For this reason I usually call for two or three original observations and mark the pupil if these are lacking. Toward the end of the year I give the pupils more freedom and find that better results are obtained by outlining general points for observation and report. Sketches and drawings test the pupils' knowledge better than words and should be called for constantly. The camera is also a great aid.

Where the Geological Survey topographic maps are available they should be in the hands of each pupil, and routes should be traced on them and relief features identified. It is no small gain for pupils to learn their practical value. We have five pocket compasses for field use and two good aneroids. Pupils need pocket clinometers which can be made by fastening a small plumb line to a protractor. It is good training for them to be required to be as accurate and definite as possible and to learn the use of field instruments. In the coming spring I expect to teach pupils the use of the hand level. We have copper plates of a few interesting features seen on our excursions and we furnished prints to our pupils for a small sum.

The preparation for an excursion takes considerable time and we plan in the near future to have printed directions perhaps in the form of a field pad or notebook. We shall thus save the time of dictating directions and obtain notes in better form.

To properly care for the large number of pupils who go on our excursions is impossible for one person, and for several years I have chosen as field assistants three or four of the best workers in previous classes. It is then possible to form groups of about 20 pupils each and to assign an assistant to each group, who is able to aid the pupils and to keep them at their work. To call the groups together for general directions, or when I wish to explain something I use an umpire's whistle. To render it easier for pupils to hear explanations I plan to have a small megaphone.

There has been a noticeable gain in the quality of work done since I have required field notes to be submitted to me or to the assistants for approval in the field. Careless pupils have thus been prevented from making the excursion a mere pleasure trip with the chance of writing an acceptable report by borrowing the notes of some faithful pupil. It also has made it possible for those who have done poor work to do it over before leaving the place.

On the day following the excursion the pupils bring their notes to the laboratory and write their report using two laboratory periods for the purpose. The facts are then fresh in mind and this plan insures independence, and enables the teacher to help the pupil who fails to understand some feature of the field work.

The order in which excursions are taken seems to be important.

My present plan is, in the fall to have facts learned at first-hand in the field and to follow excursions with book study of the same features, while the spring trips have been planned especially to test and strengthen the observing powers of the pupil and to serve as a practical review of facts already learned.

For the first excursion we visit a quarry. This gives us a very limited area with few and simple problems. The pupils study and describe the rock structure, stratification, joints, synclines, anticlines, and weathering and bring back for laboratory study specimens of limestone, hornstone, shale and residual soil.

The same features are studied in other places in the next two excursions. This gives an opportunity for comparison and it also helps to correct false impressions gained on the first excursion. For example, I find a tendency for pupils to think that a joint is a peculiar phenomenon found in one part of one quarry, and the idea of a system of joints is not easy for them to grasp. Again this plan enables them to realize the fact that the soil is everywhere underlain by rock, an entirely new idea to most of them. In these excursions in addition to the comparative study of the rock structure one or two new features are added each time.

The most comprehensive excursion is saved for the last, in order that the pupils may get the most possible from it and that there shall be no anticlimax.

To the teacher who has not yet planned a set of field excursions some hints as to how to set about it may be of interest. Use all available helps in getting acquainted with your region, the United States Geological Survey maps, State geological reports, and bulletins. Talk with those who know the region if you can find such persons. Outline the features that are probably found in the region. Visit promising places that are not too difficult of access by students. Take notes on what you find and where, and make these notes the basis of directions to students.

Most regions in New York State furnish illustration of all the causes and results of weathering and erosion, of the various phenomena connected with young and mature drainage, of shore features as exhibited in lakes or ponds, and of glaciation. I find it possible to have my pupils study in the field every topic under the land and land waters except mountains and volcanic action. The places most worthy of examination and giving the richest results will probably be stream valleys, quarries and other places where the rock is exposed, roadsides and excavations of earth, and the shores of ponds or lakes.

Summary

The chief aims of field work are, (*a*) to develop a love for nature study and (*b*) to train and inform the student.

The difficulties to contend with are number of pupils, distances often necessary to reach interesting regions, expense, weather and the immaturity of the child.

The plans suggested are:

1 For early excursions, detailed directions and definite questions requiring one or two original observations are furnished pupils.

2 For late excursions, general directions are given.

3 The use of topographic maps and the making of drawings and sketches in the field are suggested.

4 To secure accuracy, pocket compasses, aneroid barometers, clinometers and levels should be taken into the field.

5 If the number of pupils is large, student assistants who lead groups of 20, make the work more effective.

6 It has been found advantageous to approve pupil's notes on the field.

7 The report is written in the laboratory the following day.

The following suggestions are made as to the order of excursions:

1 The first excursion to precede the study of the subject in books.

2 The last excursions to illustrate facts already learned.

3 Early trips should have simple problems and limited area.

4 Repetition of similar features with some new problems is useful for review and comparison.

5 The best excursion should be reserved for the last.

Ways of going about the planning of field excursions are suggested.

THE VALUE OF THE INDUCTIVE STUDY OF RELIEF FORMS IN FIELD WORK AND CONTOUR MAPS

BY WILLIAM H. PLATZER, POUGHKEEPSIE HIGH SCHOOL

Suppose we limit the subject to the inductive study of relief only. This will make the discussion more specific. In doing this the thoughts that I will present have been gathered from my experience in the classroom and field, as I claim no special knowledge of geology or pedagogy. I am glad Dr Hopkins asked me to prepare this paper for it has brought clearly before my mind the points on which I need to ask questions of others. I hope to provoke such a comprehensive discussion that it will help me in the solution of some of my problems.

To one who has followed the syllabus of 1900 with a class it is evident that there were a great many facts to be taught that could never be more than mere facts to the student because of the limited time given to the course and the purely textbook method of procedure. All the matter presented may have had a definite enough place in our own minds, but if we were to stop to consider just how that knowledge came to be systematized most of us would find that it was not gained in the five months' study of this subject in a high school. I fear that some of my reviews at the end of the term were mere catechisms. A science teacher in one of the New Jersey high schools who had been placed on a committee to draft a syllabus of physical geography told me that he believed he would recommend that the subject be dropped from the high school course. He only thought of the subject as we taught it according to the old syllabus as a mere collection of facts about the earth and the physical sciences. The great trouble is that as students and teachers we failed to see in the brief glimpses of physics, chemistry and biology, a gradual development of our earth or if we saw it we had failed to find the means of unfolding that idea to others.

The average student who comes to us from the well taught graded school has such a conception of the relief forms of the earth that there is no necessity for us to attempt any inductive work in the study of the form itself. The pupil, however, has still to learn the processes by which such forms were attained. If the true scientific spirit is to be carried into our work in physical geography this should be done by the inductive method.

Here is our opportunity to make the best use of field work and contour maps. I prefer to have the first laboratory exercise in the field and do not think of using a contour map until considerable field work has been done, nor do I use a map where the material for the lesson can be obtained from the field.

Although it may seem more logical to take up the work on the atmosphere first, we have found it at Poughkeepsie a matter of convenience to begin with the land. This is because of the fine opportunity that we have to study the cycle of erosion there. We give most of the time allowed for field work to this feature and find that the observations on the atmosphere can best be made in the latter part of the school year.

Allow me to use as an illustration the way we have studied the development of flood plains. A meadow just east of the city furnished our material. The value of the field for this purpose is increased by the fact that a small stream meanders through it. The class each time went to the field provided with small notebooks and a sheet of questions designed as a guide in the work. One of the first things that they were asked to do was to discover the origin of the material of which the plain is composed. They never found trouble in solving the problem after they had compared the soil with the material found in the various curves and other protected places along the stream course. There was always some boy in the class who had seen the meadow flooded in the springtime and who could locate some of the material left at that time.

In like manner by asking the pupils to determine what seemed to be the highest and driest part of the plain it was not difficult to bring out the idea of the development of the natural dikes. I found that to do this it was necessary to lead them through a series of reasoning on the variation of the transporting power of water. It also became evident that one could not rely altogether on a prearranged direction sheet for this purpose. It was easier for me to explain the transporting power of water in the field than in the classroom.

The presence of curved marshes in the meadow furnished the material for the study of oxbow lakes and their disappearance. Such other features as could be used were studied and the students were left to work out for themselves what would be the effect of the continual shifting of the meandering stream. This was followed by the textbook study of the valley of the Mississippi and the detailed study of the Donaldsonville topographic sheet.

The value of this plan of procedure over the purely textbook method was tested last fall in our work. On a written lesson which included many features of old stream courses the class was asked to explain the process of the formation of alluvial fans. This was one feature which we did not happen to find in the field and nearly the whole class failed on that question while all answered correctly the questions covering the work studied in the field.

In discussing diastrophism we have to content ourselves at Poughkeepsie by studying the folded strata exposed by the railroad cuts. When the idea of the original position of stratified rock has been fixed it seems possible for the student to get some idea of the changes which have resulted in the present positions. I have however found this the most difficult part of the field work.

In working out the idea of the life history of mountains I have made use of the Harper's Ferry and Natural Bridge topographic sheets. It is certainly necessary to spend some time in preparing a class for this kind of work. My class began by building profiles of an imaginary island and then a contour map of the island and locating a stream course on the island. They then constructed profiles of the natural dikes on the Donaldsonville sheet. I have found that with this amount of preparation the average student could begin to interpret contour maps as to elevations and depressions. In studying maps of mountainous sections I have the student give as much as he can of the origin of the ridges and depressions and always his conception of the appearance of the country in a previous stage of erosion. The section is also considered in its relation to man.

After the ability to use the contour map has been acquired I believe that the mere mechanical work with the map should cease. I have never required more than one profile map of a student and this for two reasons. First, this phase of the work soon develops into mere busy work. Second, unless the time is largely spent on work which calls for some amount of thought the main object of the laboratory work is lost.

My experience has demonstrated that the laboratory sections should be small and that all should be at work on the same map at the same time. By all working on a map of the same section all the members may get the benefit of the questions asked by both students and teacher. Of course cases do arise where students will depend too much upon other members, and one might wish that adjacent students were not at work upon the same maps.

The directions given to the student for the study of the map should not be much more than outlines and the teacher must be ready to lead discussions and ask questions as the work advances. As a result of a discussion started one day in our class one of the girls had the old and well fixed idea that a volcano is a burning mountain, rooted out of her head by settling the fact that Mount Shasta was a volcano long before that part of the cone which rises above 8000 feet of elevation was formed.

Our work on contour maps included the study of coastal plains, lake plains, flood plains of rivers, plateaus and mountains. In nearly all cases maps have been selected so as to show the effects of erosion on these features.

I can not see why classes that can visit coastal plains or a seashore can not work out inductively the formation of that class of plains and then by the aid of proper contour maps be led on to the development of the plateau. The combination of the field work at hand with the properly selected contour maps will make possible the inductive study of the life history of even our everlasting hills.

We have arranged our laboratory work to alternate with the class work whenever it is needed for inductive study. Of course sometimes this is not more than a demonstration. It is harder to arrange the field work so as to introduce topics with their related field work for the weather and other school plans have to be considered.

I believe too much effort can not be made to keep the work of the field and laboratory from becoming mere mechanical drill. The less diligent students are apt to be satisfied with answers to questions of detail. For that reason the directions given the student should be as far as possible questions involving some amount of reasoning and not calling for direct answers.

A laboratory course in physical geography is a new departure in our educational system and it certainly deserves a distinct place. I tried to introduce a laboratory course in physical geography in the school where I was teaching two years before the present syllabus was written and succeeded in getting permission of the superintendent to have field work and map building. I believe even that concession was more than could have been obtained under a superintendent less interested in scientific work. A new course may be expected to have its imperfections and we have no doubt much to learn as to just what to give and how to present it. It does seem to me that some of the experiments suggested in the present syllabus are beyond the second year student. In fact I am sure that no one of our second year students could grasp all of them. Is it not true that the Department's directions for the study of contour maps are in many cases too long for the time we have to give to them?

I believe that the introduction of laboratory work in physical geography is a step in the right direction by means of which we are going some time to give the student a splendid opportunity to develop scientific habits of thought. By the inductive study of the phenomena which he constantly sees, valuable information will be given. He will go into the physical sciences better prepared for scientific work and he will obtain a glimpse of the possibilities of matter and energy which he could not otherwise acquire outside of the college.

Section D — MATHEMATICS

THE PLACE OF THE THEORY OF TRANSFORMATIONS IN GEOMETRY

BY A. S. GALE, UNIVERSITY OF ROCHESTER

During the last century the domain of geometry has grown to tremendous proportions and yet the theory of transformations permeates the whole domain. We may use it whether we employ the synthetic method of the Greeks or the analytic method of Descartes; whether we study algebraic geometry, in which we consider the properties of a figure as a whole, or differential geometry, which deals with the properties of a figure in the vicinity of a particular point. An exhaustive treatment of the place of the theory of transformations in geometry would therefore entail not only a development of the principal properties of various transformations, but also the consideration of a large part of geometry as a whole. And yet two salient points may be brought out by simple considerations. The object of the paper is to illustrate how the properties of a single transformation enable us to derive new theorems with great ease, and to show how certain systems of transformations form the basis for a comprehensive classification of the theorems of the vast subject of geometry. In particular, we shall see what part is played by the elementary geometry in which we are so vitally interested. In this, perhaps, lies the real justification for laying such considerations before this body. In passing, it may be remarked that certain elementary portions of the theory of transformations may be included in secondary instruction at some future day.[1]

With sufficient accuracy for our purposes, we may define a transformation as an operation which replaces, according to some definite law, a given configuration by a second configuration. Simple examples are a displacement, which replaces a given figure by one equal to it, and transformations of symmetry and similitude by which a given figure is replaced by one symmetrical or similar

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[1] Synthetic treatments of Euclidean transformations and inversions have already appeared in the very excellent Géométries Elémentaires by Hadamard [Paris, ed. 2, 1906] and Niewenglowski et Gérard [Paris, 1898]. An analytic treatment of these transformations, together with polar reciprocation, may be found in Smith and Gale's *Elements of Analytic Geometry* [Boston, 1905].

[illegible] These transformations are known as Euclidean transformations because they are implied in the classic *Elements* of Euclid.

An *inversion* is a transformation which replaces any point P by a point P' such that

1. P' lies on OP, where O is a given point called the center of inversion.

2. $OP'.OP = k$, where k is a constant.

If P describes a given figure, P' describes a second figure called the inverse of the first. Thus the inverse of a straight line which passes through O is the same straight line, while that a straight line not passing through O is a circle which passes through O. The inverse of a circle passing through O is a straight line, while the inverse of a circle which does not pass through O is a second circle.

A fundamental property of inversion is that the angle between two curves equals the angle between the inverse curves. As an application of this property, consider the problem of constructing a circle which shall pass through a given point, O, and cut each of two given circles, C_1 and C_2 at right angles. If we invert the figure using O as the center of inversion, C_1 and C_2 become two circles C'_1 and C'_2, while the required circle, since it passes through O, becomes a straight line which must cut C'_1 and C'_2 at right angles. This line is therefore the line of centers of C'_1 and C'_2. Inverting this line we obtain the required circle.[1]

As another application, invert three lines which form a triangle. We obtain three circles which have a point in common, and since the magnitude of an angle is unchanged by inversion, it is evident that *the sum of the angles of a figure formed by arcs of three circles with a common point is two right angles.* To make the proof general, it is necessary to show that every such figure may be obtained by inverting a triangle. To do this, it is sufficient to invert the three circles, taking their common point as the center of inversion.

For further illustration, consider a simple form of *projective*

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[1] Problems of construction have been systematized by means of the simple transformations mentioned so far by the Russian, Alexandroff, and the Dane, Petersen, whose books have been translated into French and German. Petersen's has also been translated into Italian and English, the latter appearing under title of *Methods and Theories for the Solution of Problems of Geometrical Constructions* [Copenhagen, 1879]. Further literature is given in the chapter on elementary constructions in the admirable treatise edited by Enriques, *Questioni riguardanti la Geometria elementare,* [Bologna, 1901], a German translation of which is being issued by Teubner of Leipzig.

transformation defined as follows: The points of a figure F in a plane α are joined to a point O not in the plane α, and these lines are cut by a second plane giving a second figure F'. To any point P in α corresponds the point P' in which α' cuts OP. To a line l in α corresponds the line l' in which α' cuts the plane of O and l, and to intersecting lines in α correspond, except in special cases to be considered in a moment, intersecting lines in α'.

Parenthetically, it may be remarked that the theory of transformations gives an interesting point of view for the mathematicians' convention concerning the infinite region of the plane. If we invert a point P, we obtain one and only one point P', unless we allow P to become coincident with O or to recede indefinitely from O. If P approaches O, P' recedes indefinitely from O in a direction dependent upon the fashion in which P approaches O, so that to O itself corresponds any point at infinity (using the word in a naïve sense). As P recedes indefinitely from O in any manner, P' approaches O, so that to any point farther from O than we can ever get, corresponds O itself. To avoid constant reference to this exceptional behavior of O, when working with inversions we arbitrarily agree to call the infinite region of the plane a *point*, the inverse of the point O. On the other hand, if we project a point P we obtain one and only one point P' unless OP is parallel to α', when the position of P' is not defined. We have this state of affairs, not for a single point as in inversion, but when P is any point on the line i in which is cut by the plane through O parallel to α'. To every line l in α, corresponds one and only one line l' in α' unless l coincides with i. If L moves in the plane α and approaches coincidence with i, it is easily seen that l' recedes indefinitely. Hence when working with projective transformations we arbitrarily agree to call the infinite region of a plane a *straight line*, the line at infinity. To any point on i in α corresponds a point on the line at infinity in α'; but it happens that lines in α which intersect on i project into parallel lines, and hence we are led to say that "parallel lines meet at infinity." In this apparent contradiction of terms, the verb to meet has lost its ordinary significance, the word infinity has been robbed of its usual naïve meaning, and the phrase as a whole is nothing but a technical term for a mere convention. Thus in working with inversions, we are led to regard the infinite region of the plane as a point, when dealing with projections we treat it as a straight line, and from the standpoint of some other transformations we might regard it in some entirely different light.

If we consider a circle in the plane α, and draw the lines through its points and a point O in the line perpendicular to α at the center of the circle, we obtain a cone of revolution. Hence the projection of the circle, which is obtained by cutting this cone by a second plane α' is an ellipse, hyperbola, or parabola, according to the position of α'. This enables us to study the conic sections by means of properties of circles. Thus it is readily proven that if a hexagon with two sides parallel respectively to the sides opposite be inscribed in a circle, the third pair of opposite sides will be parallel. Projecting this figure we obtain a hexagon inscribed in a conic, and since parallel lines meet on the line at infinity, which projects into a straight line, we have *Pascal's theorem, the pairs of opposite sides of a hexagon inscribed in a conic meet in collinear points.* The proof is general if it can be shown that every conic and inscribed hexagon can be obtained by projecting the figure with which we started. This follows readily since any conic may be projected into a circle at the same time that any line is projected into the line at infinity.[1]

Another simple transformation, which does not, however, replace a point by another point, has its origin in the theory of poles and polars. A polar reciprocation with respect to a given conic is a transformation which replaces any point by its polar and any straight line by its pole. To the line joining two points corresponds the point of intersection of their polars, and to the point of intersection of two lines corresponds the line joining their poles. Three points on a line are replaced by three lines passing through the same point. To the points and tangents of a curve correspond respectively the points and tangents of a second curve. In particular, to a conic corresponds a conic, to the six vertexes of Pascal's hexagon correspond six tangents to a second conic, to the sides of the first hexagon correspond the vertexes of the second, and to the points of intersection of the opposite sides of the first correspond the lines joining the opposite vertexes of the second; from Pascal's theorem we have at once *Brianchon's theorem, the lines joining the opposite vertexes of a hexagon circumscribed about a conic are concurrent.*

We might continue to give applications of these and other transformations, but enough have been given to show how individual transformations enable us to derive new theorems from old ones.

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[1] Salmon. Conic Sections. Ed. 10, § 366, p. 330.

Turn now to the systems of transformations necessary for classifying the theorems of geometry.[1]

If we consider all translations in a given direction, it is obvious that the result of the successive applications of two transformations of this system may be effected by a *single* transformation of the *same* system. Such a system of transformations is called a *group*. Not all systems form groups; thus the totality of symmetry transformations do not form a group, because if a figure F is replaced by F' symmetrical to F' and F by F'' symmetrical to F', F and F'' are equal and a displacement, not a symmetry transformation, can replace F by F''.

A group, known as the *Euclidean group*, is formed by all displacements, symmetry and similitude transformations. For the successive application of any two of these transformations replaces F by F'; and then F' by F'' in such fashion that F and F'' are either equal, symmetrical, or similar, and hence F may be transformed into F'' by a transformation of the system. Another group, the *group of inversions,* is obtained by adjoining all inversions to the transformations of the Euclidean group. *In space,* it consists of all transformations which preserve the magnitude of angles. The *projective group* contains all Euclidean and projective transformations. These three groups will suffice for our purpose.

The theorems of elementary geometry may be divided into two classes, according as they deal with a single figure or with two figures which are either equal, symmetrical or similar. Consider, for example, the theorem that a straight line perpendicular to a radius at its extremity is tangent to the circle. If we subject the figure to a displacement, a symmetry or similitude transformation, we obtain a circle, a radius, and a straight line perpendicular to the radius at its extremity, which is still tangent to the circle. But if we invert the figure we obtain two tangent circles, and an arc of a third circle, terminating at their point of contact. While if we project the figure we obtain a conic, a straight line tangent to it, and a segment of a straight line terminating in the point of contact, but which is not perpendicular to the tangent. Consider also the theorem that two mutually equilateral triangles are equal. If we apply the same displacement, symmetry, or similitude transformation to both triangles, we obtain two triangles which are mutually equilateral. But if we project them we obtain two triangles, which are not mutually equivalent, and if we invert we do not even get two triangles.

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[1] These ideas were developed at length by Klein in his *Erlanger Programme*, 1872. A translation, entitled A Comparative Review of Recent Researches in Geometry, may be found in the *Bulletin of the American Mathematical Society*, first series, volume 2 [1892–93], page 215.

We notice in these examples that the figure and content of the theorem are essentially unchanged by a transformation of the Euclidean group but that they are changed when the figure is subjected to any other transformation. We say, then, that Euclidean geometry consists of those properties of figures, which are unchanged by the transformations of the Euclidean group, but which are changed by other transformations. Projective geometry consists of those theorems, like Pascal's and Brianchon's, which are unaltered by a transformation of the projective group, but which are changed by other transformations such as inversion. We study also in projective geometry, pairs of figures which may be projected into each other. In like manner, the so called geometry of reciprocal radii is associated with the group of inversions, and, indeed, with every group is associated a certain body of theorems, which form the geometry of that group. In this fashion the theory of transformations enables us to classify the theorems of geometry.

CONCERNING THE INTRODUCTION OF MODERN NOTIONS INTO THE GEOMETRY OF SECONDARY SCHOOLS

BY C. J. KEYSER, COLUMBIA UNIVERSITY, NEW YORK CITY

Of all the diverse forms of tyranny, none is more austere and lasting than that by which a high towering summit intellect of any age sways and controls the thought of succeeding ages. The blazing light of a great genius may blind the eyes of generation after generation of men. For 2000 years the imposing creation of the Aristotelian logic seemed to men to be a thing perfect, complete, almost divine. To attempt to improve it or to supplement it was regarded as hopeless; to propose such an attempt was often looked upon as impious. At last the yoke has been shaken off. The student of logic now knows that the Aristotelian system, however important and indispensable, is but a suite of rooms in the great palace of modern logic now rapidly rising in accordance with the designs of such modern architects as Boole and C. S. Peirce, and Schröder and Peano. The master dramatists of Greece exercised a sovereignty for centuries and the effectual overthrow of the tyranny of the "unities" had to await the genius of the Elizabethans. Examples illustrating my thesis of the too long enduring domination of a single genius abound in the history of man, in science, in letters, in art, in religion, in philosophy, in statesmanship. In case of Euclid's *Elements*, the reign is broken but emancipation is by no means complete. Particularly in secondary education, the ancient authority, though its rigor has been relaxed and its perfection impaired, still prevails to the exclusion of modern spirit, modern ideas and modern modes of procedure.

I am opposed to this persistent regnancy of tradition and plead for the extension of a magnanimous hospitality to the living geometric thought of modern days. In this brief address I wish to indicate in an entirely informal way a few of the changes that I think it highly desirable to make in the mathematics and particularly in the geometry of the secondary school.

Let me begin with one of Euclid's axioms, namely that which states that the whole is greater than any of its parts. Now Euclid considers only *finite* magnitudes; his lines have beginning and end; they are line segments merely; similarly his planes are but finite, bounded pieces of plane; and so on. Now his so called axiom holds good for finite magnitudes but it is not axiomatically applicable to them. His proposition, then, holds good for the sort of magnitudes he considers, but it is not axiomatic. One must first know what is meant by finiteness of magnitude and then inquire whether the proposition is valid respecting such magnitude. Now the modified Euclid that you probably teach not only retains the so called axiom but admits infinite magnitudes, such as beginningless endless lines and boundless planes. As applied, however, to infinite magnitudes, the axiom is not only axiomatic but it is always false. You are bound, therefore, either to exclude infinite magnitudes from your geometry as Euclid did or to exclude the axiom. Even if you exclude the infinite magnitudes and retain the axiom you may not retain it as self-evident. But if you exclude infinite magnitudes and keep finite ones only, you must do so *in terms*. But that requires you to tell what you include and what you exclude. You can hardly define either the finite or the infinite without at the same time defining the other. Hence you must define both. That done, you may as well keep both and then show that the so called axiom is simply a proposition that always holds for the one kind of magnitude and never holds for the other kind. The upshot is that among your geometric axioms you must not have the statement that the whole exceeds its part.

The like considerations hold in your algebra, where you deal with multitudes as distinguished from geometric magnitudes. Multitudes may be finite or infinite. The definitions must be given, and then it will appear that the so called whole-part axiom is simply a property of every finite multitude and never true of an infinite multitude.

Doubtless you think it time to ask: what is the finite? What is the infinite? And how make the notions clear to a high school pupil? Well, you are right. In the first place let me caution you against shrinking from the task. No idea is simpler, easier to apprehend, than the notion of the infinite. In fact, it is so near lying and so obvious, so writ on the very surface of the eye, that people failed to see it for nearly or quite 2000 years. Meanwhile no one was smart enough to tell satisfactorily what he meant by the finite. Now any high school pupil fit for instruction may be readily taught to define both the finite and the infinite understandingly. It is of great importance to afford this instruction not only for the right understanding of algebra and geometry but more especially to equip the minds of the young with such concepts and distinctions as they can later in life acquire only with difficulty and as are absolutely essential to any competent participation in the thought of the coming day. Do not lose sight of the fact that from among the boys you teach are to come the theologians, the philosophers, the scientists of the future. Nothing is more certain than that the progress of philosophy, the advancement and clarification and rationalization of theology, the depth and critical facility of science, all depend largely on the mastery of certain instrumentalities and notions that modern mathematics is prepared to contribute to thought, and of such notions none is likely to play a more distinguished rôle than the notions of the finite and the infinite.

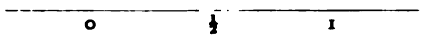
I suspect it is best to begin with the notion of multitude — to make clear to the pupil what a finite multitude is and what an infinite multitude is. Many are the easy means of doing this and the game may be played with variations. Let the teacher know how to play the game with facility and the pupil will join with eager and intelligent interest. Let me briefly indicate two or three ways of doing the thing. Consider the sequence of integers 1, 2, 3, 4, 5, ... n, n+1, ... A little easy dialectic will serve to convince the pupil that the sequence continues endlessly. He will soon prove to you that it has no last term. Write the sequence of even integers under the other, thus:

$$\begin{array}{l} (a)\ 1, 2, 3, 4, 5\ \ldots\ n, n+1\ \ldots \\ (b)\ 2, 4, 6, 8, 10\ \ldots\ 2n, 2(n+1)\ \ldots \end{array}$$

Now treat the figures as things merely. Pair 1 with 2, 2 with 4, and so on, *i. e.* each thing in (*a*) with the thing under it in (*b*). A one-to-one correspondence is thus set up between the things in (*a*) and the things in (*b*). Make much of this notion of one-to-one correspondence. It is fundamental in all thinking. By this means the pupil will see that there are just as many things in (*a*) as in (*b*) and no more. If in a flock of sheep and a herd of cows, there is one cow for each sheep and one sheep for each cow, then there are just as many sheep as cows and no more. Next lead the pupil to see that (*b*) is a part of (*a*); that is, that everything in (*b*) is in (*a*) but that there are some things in (*a*) not in (*b*). He will then see that (*a*) is a whole of which (*b*) is a part and that the part is equal to the whole, in the proper sense that there is just one thing in the part for one in the whole and conversely. The pupil will thus see that there really are groups such that the whole group is exactly equal to some part of the group. Such a group, or class, or ensemble, or multitude, is said to be infinite. Let the pupil repeat the discourse, lead in a reproduction of the dialogue, leading to the result — the concept of an infinite class of things. He will astonish you with his facility and acumen. Then show by the pupil's co-operation that there are also classes, say the class of pupils in the room or the class of trees on the continent or the class of sand grains on the shore, such that the whole class has no part equal (in the one-to-one sense) to the whole. Such a class is finite.

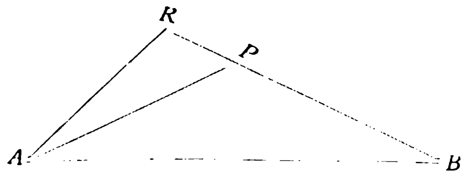
Hence a class being given, the question may always arise whether it is finite or infinite. It must be one or the other and can not be both. Here one may exercise the pupils with the liveliest interest in telling whether and why classes mentioned by the teacher or themselves are finite or infinite. They might speculate on which are the more numerous, of more frequent occurrence, finite collections or infinite collections. Quickly will they brand the old whole part axiom as absurd. Later, too, will the best of them gain an enhanced sense of the dignity of man in finding that man is not a poor, puny, finite thing incapable of dealing with the infinite but that on the contrary he knows precisely what he means by the infinite and can wield the idea without vagueness in his thought. Here lies the way to improvement in theology.

In this connection permit me to play the game as it was played in about 1858–59 by one of the pioneers, Bernhard Bolzano, philosopher, theologian and brilliant mathematician. Take some simple equation like $2y - x = 0$, or $y = \frac{1}{2}x$. The pupil will readily see that for every value of x there is one and but one value of y, and conversely. That is, there is a one-to-one correspondence between the class of x values and the class of y values. He will see, too, that the class of y values is a part of the whole class of x values. Hence the class of x values is infinite. You can readily lead him to see, too, that if a part is equal to the whole, the part is infinite. To vivify the Bolzano illustration proceed as follows: Draw a line and on it take a zero point or origin and on one side, say to the right, mark off a length and call it 1. On the line lay off the



various values of x and the corresponding values of y. A value of x will bring you to a point, and the corresponding value of y to a point (in general different from that of x). If $x = 1$, then $y = \frac{1}{2}$; if $x = \frac{1}{2}$, $y = \frac{1}{4}$, if $x = 0$, $y = 0$. As x takes all values beginning with zero and ending with 1, y will take all values beginning with zero and ending with ½. In other words, as x takes all positions or points from point zero to point 1, y takes all points from point zero to point ½ and no others. Every time x takes a new point, so does y. It is clear that thus a one-to-one correspondence is set up between the class of points on the segment from zero to ½ and the class of points on the segment from zero to 1. But the first class is a part of the second class, the whole. Hence the class of points on the segment from zero to 1 is infinite. So, too, for any other segment however long or short. There is no "trick" about this. We have not shown that the short segment is equal in length to the long one. What we have shown is that there are just as many points on the part segment as on the whole segment and no more or less.

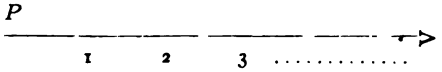
Illustrations abound in endless variety. We are immersed in a sea of them, and only a little ingenuity will enable one to appropriate the waters. I will content myself with a single other example that fairly shocks one with its obviousness. This time take a line two units long and from one end another of one unit as in the figure. Let AB be two units, and AP one unit. Join B to P and any point



R of this line to A. Then join R to all points of AB. In so doing you join R to each point of AP. A one-to-one correspondence is thus set up between the points of *AB* and the points of *AP*. This being done, turn *AP* about *A* till it falls along *AB*. *P* will fall on the mid point of *AB*. You have then a one-to-one correspondence between *all* the points of *AB* and the points on half of *AB*. Whence it again appears that there are just as many points in a long as in a short segment and that the group of points on any segment, no matter how short, is an infinite collection.

Invent and lead the pupil to invent exercises. Let him show that there are just as many points inside as outside a circle, just as many inside as outside a sphere or marble. Let him apply the definitions of finite and infinite to show such things as that the class of numbers between 5 and 50 is finite, that the group of leaves grown in a year or a million years is finite, that the group of fractions between 1 and 2 is infinite, that the group of lines or of triangles or of circles in the plane is infinite, that if one could live for ever and write in two years the autobiography of one day, every day would get written, that is no day but would in course of time be written. When would the tenth day be written? The ten millionth day? The n^{th} day?

Thus far we have talked mainly of multitude. Let us turn now to magnitude, such for example, as we deal with in geometry. How shall we define infinite magnitude? Finite magnitude? The procedure must be suitable for high school use. We are to say, not the last word about it, but rather a right first word. A natural beginning is as follows. A magnitude will be called finite if when you come to measure it you find it contains a finite number of units, like the inch or foot. That is you define finite magnitude by help of the notion of finite multitude (namely of units). Similarly for infinite magnitude. Consider the line beginning at any point *P* and proceeding onward endlessly. To that notion the pupil will offer no resistance. Treat this half line as a magnitude. Is it a finite



magnitude? Take any ordinary unit, as a foot say. Lay it off a few times and mark the divisions in order with the integers 1, 2 ... Consider the class of sections (units, in this case feet) so obtainable. Ask the pupil to notice the two movements, movement along the line and movement along the integer sequence. Will one movement carry you further than the other? Has not the line a division point for every integer in the sequence? The pupil will say yes. Is there not an integer for each division point? Again he will say yes. There are just as many feet (units) in the line as division points and just as many division points as numbers in the class of integers. But the class of integers is infinite: so, then, the class of units (feet) in the line is infinite. The line, then, is not a finite magnitude. We call it an infinite magnitude. If we put *P* where 1 is, and 1 where 2 is, and so on, we shall have just as many units to the right of the new *P* as before. That is the old magnitude is equal to the new. The new is, however, but part of the old. So you see that in case of magnitudes as in case of multitudes, an infinite whole has a part equal to the whole. One may easily show that a finite magnitude exceeds any of its parts. Let us away, then, with the vicious old whole part axiom in geometry as well as in algebra. Note, too, that we might as well take the yard or meter for unit. The infinite line running out from *P* contains exactly as many yards or meters as feet. Such a statement is of course not true of a finite line, one, that is, that both begins and ends.

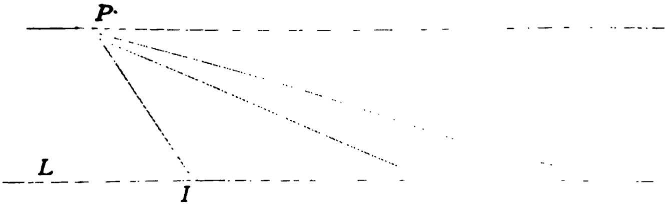
Next consider the whole line running both ways from *P*. Mark off the units to the left of P by the integers $1', 2', 3' \ldots$ Now pair as follows:

$$(a)\ 1, 1', 2, 2', 3, 3' \ldots n, n' \ldots$$
$$(b)\ 1, 2, 3, 4, 5, 6 \ldots 2n, 2n+1 \ldots$$

So the pupil will see that collection (*b*) has precisely as many things as collection (*a*). But the whole line has just as many units as (*a*) and the part line just as many as (*b*). So it is seen that the part line is just as long as the whole line. How long then is the beginningless endless line? Answer: It has just as many units of a chosen kind as there are integers in the collection of integers.

It is easy to see that there is no number in (*b*) that tells how many integers in (*b*) for any given number in (*b*) tells how many in (*b*) up to and including the given number but beyond the given number the integers go on endlessly. Hence if we wish to say how many numbers in (*b*) we must use another sign or symbol, say *a*. This number *a* is, then, to tell us the number of things in a collection containing as many things as (*b*). How many feet or yards or miles in a whole line? The answer is *a*. This *a* is an infinite number and it is a cardinal, too. How many units does a line stretch out from one of its points? The answer is *a* units. On beyond? No.

I am here speaking of the line of parabolic geometry, the kind the pupil unconsciously believes in.



I should not fail to acquaint the pupil with the notions of range of points and pencil of lines, and, in that connection, with the notion that parallel lines meet at an infinite distance, i. e. at a distance equal to a units. He will readily see that to any point I of line L there corresponds one line through P, namely PI, and that, conversely, to any line through P there corresponds one point I of L, except that to a line through P parallel to L there seems to be no point on L. This single exception to the correspondence is annoying. How shall we get rid of it? We do it by agreeing to say that the parallel does meet L, not in a point whose distance is a finite number of units away, but in a point a units away. We call this point the infinite point of L. We agree to say that a line has just one point at infinity because one such point removes the one exception, the single source of annoyance, above noted. Euclid has nothing to do with such points. He was a Greek. The Greek genius was dominated with a certain artistic craving, a craving for objective representability. The infinite does not lend itself to such uses. It was not Greek estheticism but the objectivity of Greek estheticism that kept the infinite out of their hearts and heads. Otherwise how different had been the course and development of western civilization, science, philosophy, religion. The infinite point of a line came into geometry less than 300 years ago by the genius of Gerard Desargues, contemporary of Pascal, Descartes, Newton and Leibniz. It is high time the notion should fertilize the geometry of the high school. Parallel lines are lines that have their infinite points in common. Rotate a line about any one of its points. Each point of the line describes the circumference of a circle. The infinite point of the line describes a circumference of infinite radius. Show the pupil that such a circumference is a straight line. Then stop defining circle as a piece of the plane. Define it as a line. So straight lines will be special circles, namely circles of radius having a units. So, too, points will be circles of zero radius. I plead not for fewer syllogisms but for more thinking, more conception, more imagination, more life and light and freedom. Let us stop trying to make poor Greeks out of good modern Americans. The Greeks were marvelously progressive. Let us follow their example and emancipate ourselves from their domination as they surpassed their ancients. That is the way to be a good Greek.

Just as the infinite points of a plane constitute an infinite circle, that is a straight line, so show the pupil that the infinite points of space constitute a sphere (surface) of radius a, i. e. a plane. Define sphere as a surface, not as a solid, so that a plane will be a special sphere.

Present the notion of dimensionality and element. Show their dependence on each other. The plane is bidimensional in points. Why? Because to fix a point you must know two things about it. For the same reason, the plane is bidimensional in lines. Let the pupil show that the plane is tridimensional in circles, that space is tridimensional in points, also in planes, that it is four dimensional in lines, also in spheres, that it is six dimensional in circles, and so on and on.

Introduce the notion of quality or reciprocity, first in the plane, then in space. In the plane the point and the line are dual elements. Two points determine a line, two lines a point; one point determines a pencil of lines, one line a range of points. Define your figures not as portions of the plane but as combinations of points and lines. Three points determine a triangle, so do three lines. Four points determine a quadrangle, four lines determine a quadrilateral. And so on. These configurations are dual in pairs and have like properties. Study them side by side. If a circle be a locus of points, it is equally an envelop of lines. If a line is a locus of points, a point is an envelop of lines. Why exercise the pupil in loci and not also in envelops? The like for space. A sphere is just as much an envelop of planes as it is a locus of points. In space, the point and the plane are dual elements. For any theorem about figures determined by points, there is a theorem about dual figures determined by planes. One point determines a sheaf of planes, one plane is a corresponding field of points. Two points determine a line, a range of points; two planes determine a line, an axal system of planes. Three points determine a plane, three planes a point. Four points determine a tehaldron, so do four planes. What is the locus of a point that varies so as to be always the same distance from a given line? What is the envelop of a plane that so varies as to be always the same distance from a given line? Such queries are of inexhaustible variety. Lead the pupil to invent and answer numerous such questions.

Rough and informal as my remarks have been, they may suffice to indicate the spirit of freedom I should like to see introduced into geometric teaching. There is no faculty of the mind that may not be thus brought into play. It goes without saying that to give freedom to the pupil the teacher must first have attained emancipation and be able to move readily and joyously in the infinitely complex web of ideas and relationships that make up that wondrous thing called the science of space.

GENERAL SESSION

Wednesday evening, December 26

THE PREPARATION OF THE TEACHER OF MATHEMATICS IN SECONDARY SCHOOLS

BY DAVID EUGENE SMITH LL.D., TEACHERS COLLEGE, COLUMBIA UNIVERSITY, NEW YORK CITY

Rhythm of history

Of all the fascinating phases of the culture studies none has more to commend itself either to our esthetic instincts or to our practical needs than the rhythm of history. The world's tastes of yesterday, its ideals, its methods of business, are discarded today to seeming oblivion, only to reappear tomorrow. History pulsates; the graphic arts flourish, they languish, they flourish again, and so on in endless rhythm; the tastes of the schools in one generation are not those of the next, but in due time reappear on the crest of the wave; religious zeal seems to have conquered the world in one century, only to be followed by a period of spiritual depression, and so throughout the range of human interests. But these pulsations, these waves of the human soul, are by no means alike; the great law of evolution decrees that each succeeding one shall have its own characteristics, even as those caused by a pebble in a pond are of increasing breadth and circuit.

Now the relation of mathematics to natural science is subject to this same law. With Thales it was close, with Pythagoras it was less so, and with the disciples of the latter it was still less; but with Plato it turns, and with Aristotle it becomes close again; with Euclid it relaxes, and with Archimedes it strengthens; and so on until modern times. See, for example, the calculus, devised as a tool for physical research; in the next generation more abstract; in the time of Laplace and Lagrange again chiefly an aid to natural science; in the next generation a subject of investigation abstract from the scientific application; and although in the hands of Lord Kelvin exactly what it was in the hands of Newton, in the average American college course of today a dull, meaningless mass of theory with few applications, with little interest, and of value far less than it might easily possess. Hence it seems to me a very hopeful sign that, even as in the days of Archimedes, of Roger Bacon, and of

Newton, the general sciences drew close to mathematics, so in this association an intimate relationship should be recognized.

Union of mathematics and science

And yet, even with this hopeful sign comes the ever present danger, the thought that the crest of the wave will be followed by a depression. For when science gives herself completely to the embrace of cold and calculating mathematics she never fails to repent, and in her repentance she again seeks her own; and when mathematics yields too much to the warming influence of science he gives of his own virility for the time and ceases to progress. When, however, each supports the other in perfect union, neither forgetting its own proper mission, then we have an offspring of ideas that grow strong and help the world to progress. It is with the desire to see such a union that I welcome the consideration of this topic by an association of science teachers.

What makes a mathematician?

This relation of science to mathematics (and be it understood that the word "science" is used for brevity in its popular sense, mathematics being even more of a science than the "sciences")—this relation of science to mathematics leads to the remark that the idea of what constitutes a mathematician, like all ideas, has had its own rhythmic progress. If you will take a small map of India and place your thumb on Bombay and your forefinger on Calcutta, and then will close them slightly and move them a little toward the top of the map, they will rest on or near the two greatest mathematical centers of ancient India, the finger on Patna where Aryabhata lived and labored 14 centuries ago, and gave us the oldest complete Hindu mathematical treatise that has come down to us; and the thumb on Ujjein, where a century and a half later Brahmagupta made a mathematical Mecca for his countrymen. This sage of Ujjein has given us a definition of a mathematician, and one which we may well consider in thinking of the making of a teacher; for, primitive though it be, it is not without its suggestiveness. Brahmagupta says: "He who distinctly and severally knows addition and the rest of the 20 logistics, and the eight determinations, including measurement by shadow, is a mathematician." (I might pause to inquire, in view of this definition, if there is a mathematician here present.) Now what does this mean? Brahmagupta's 20 "logistics" were: our four fundamental operations, squares and cubes, with their respective roots, five rules in fractions, the rules of 3, 5, 7, 9, 11, and barter; his eight " determinations " were mixture, progression, plane figure, excavation, stack, saw, mound and shadow — to use his own phraseology. Now the details of all this will not interest us particularly, but the quaint language may catch our attention sufficiently to have us remember that a mathematician is not merely a man who knows the theories of the subject, but one who is able to use those theories in a practical way. And this has generally been the case with the world's greatest leaders in this field. Archimedes, for example, wanted higher mathematics that he might use it, and so he laid the foundations of the calculus nearly 2000 years before Leibnitz and Newton, building immediately upon the works of Kepler, Cavalieri, Fermat and Descartes, created the science as we know it. And so these other men just named, and Euler, Laplace, Lagrange, Legendre, Monge, Gauss, Cauchy, not to speak of Klein in our own day, men whom we look up to as among the world's greatest mathematicians, all knew the larger uses as well as the mere theories of this oldest of all sciences.

The teacher vs. the mathematician

Now a teacher of mathematics stands somewhat apart from the mathematician himself. I know very few men of recognized standing as investigators in mathematics whom I would dream of recommending as teachers of the subject; neither do I know many who are today molding the teaching of mathematics whom I would recommend for positions requiring original investigation in mathematics. And this is merely a corollary to a psychological proposition; if our brain cells have become so formed or so interrelated that we, at adult age, have interests abnormally along one line, it is exceedingly difficult for us to concentrate attention on another line. We express this in a homely way by telling the cobbler to stick to his last. So it is only fair to say that an ideal teacher, an exceedingly difficult person to find, while possessed of an all round knowledge of mathematics and interested in seeing it develop, can not be expected greatly to assist this development by his own original discoveries. On the other hand, a man who is doing really great work in mathematical investigation, and such men are also exceedingly difficult to find, while interested in seeing the subject well taught, can not be expected greatly to assist in advancing the educational thought by his own efforts. The great teacher and the great mathematician are equally rare; they are equally to be honored; but they are never combined in one individual. And between these extremes the law still holds; as a man leans to the one side, his interests fail in the other.

Doubts as to professional training

Now this law is often denied, both by original investigators in education and by original investigators in mathematics. We have in this country a good many pretty fair teachers of mathematics who think that they are great mathematicians, and it may be well that they should think so, since it increases that all round interest in the science which it is so necessary for them to possess; but in reality they are mere dust floating about in the gigantic machine. On the other hand we have a good many men who are contributing more or less to the progress of mathematics, and who think they are great teachers, when they are ignorant of even the primary principles of education, usually even doubting that such principles exist. The one who is interested primarily in teaching, sometimes displays his ignorance by openly expressing nonappreciation of the work that is being done in higher mathematics, and thus he shows a narrow mind that excites the pity of all who fairly look at the progress of the world. On the other hand, the one who is interested primarily in mathematical research sometimes displays his ignorance by openly expressing his disbelief of the work that is done in the professional training of a teacher, a training which would at one time, when his mind was receptive of something besides mere mathematical truth, have been a service to him. This antagonism to matters educational arises from the fact that there was for a long time a tradition among those who ranked themselves as scholars that the guild of teachers burned incense before some fetish called method, without worshiping at the altar of true knowledge; that its members bowed before form without content, shadow without substance.

In the early days of normal schools, and long before the professional college was thought of, there may have been some justification for the charge. But with the rise of the standard normal school of today, with at least two years beyond a four years' high school course, usually combining advanced academic work with the professional, and with the birth of higher professional colleges, and with the growth of special training in other professions, the tradition has lost its earlier dogmatic form. Two generations ago physicians often asserted that the knowledge required for their fraternity was best obtained in the office of a good practitioner, but today we require not only graduation from a good medical college, but even postgraduate work. The lawyer, the preacher, the nurse, the bookkeeper, and the teacher as well, all demand knowledge peculiar to their several professions, and in advance of that of their immediate predecessors.

Growth of the demand for professionally trained teachers

These facts have been so generally recognized that there is a rapidly increasing demand for professionally trained teachers of mathematics, as of other subjects, in secondary schools and colleges. The time was when part of this demand was satisfied by graduates of academies and normal schools, but this time has passed. The smaller villages may still have to employ such teachers, and unless they will pay enough to get a good class of college graduates it is better that they should; but all of the more responsible positions now demand the college degree, and rightly so. In addition to this, a graduate professional year is coming to be required wherever it is possible to find candidates who have taken it, and the future will see the doctor's degree demanded, plus or together with this advanced professional training. Last year half a dozen of my graduate students secured positions on college faculties, a fair index of the value placed upon the professional work by the very institutions that recently were doubtful of the advantages of a course in education.

Nature of the work of making a teacher of mathematics

This too long preliminary discussion brings me to the question as to the preparation demanded today for a satisfactory teacher of secondary mathematics. I say "today," because tomorrow will demand more, and I say "secondary," meaning to include high schools, normal schools and the freshman year in college.

In answering the question, it is unnecessary to discuss the matter of personality. That is largely beyond the powers of the professional school. All that we who are training teachers can expect to do is this: other things being equal we can make what we sometimes hear called a "born teacher" much better able to do good work, saving him from a multitude of blunders and showing him the large questions which he should not allow to be obscured by a multitude of unimportant details.

First, what academic work does he need in mathematics? As a minimum he must have two years of college work, carrying him through the elements of the calculus. Any less than this would unfit him intelligently to handle either geometry or algebra. In addition to this my own students are practically required to take projective geometry because of its bearing upon the Euclidean science, and the advanced theory of equations because of the light which it throws on algebra. But most of my graduate students take much more than this, the theory of functions, differential equations, solid analytics, the theory of surfaces, and modern ideas in geometry being the courses from which selections are most frequently made. My recommendation is that every student shall take as much work as possible in pure mathematics, consistent with the other important demands upon his time. Of these demands one is that of applied mathematics. I am urging more and more strongly that our students should take courses in general applications (and we have recently established such a special course for teachers), in mathematics and in astronomy. Any other plan would fail to give that balance between pure and applied mathematics which is necessary to the making of a teacher who would show the practical uses of the subjects which he treats.

Secondly, what professional courses does he need? In the first place he should know how mathematics has grown up. Ignorance of this fact would tend to make him unprogressive; he would look upon mathematics as a fixed science, undeveloping and undevelopable. This is the attitude of mind of the majority of teachers today. Against any proposed change they invoke the fetish of "mental discipline," believing, with an ignorance fostered by indolence of mind, that what has been good enough for the past should be sufficient for the present. Hence at least one year's work in the history of mathematics is demanded of all of my students, and a second year's work is advised, and I know of no better stimulus than this for the appreciation of a purely professional course. To know how elementary geometry has been crystallized in its present form, is almost a *sine qua non* to intelligently considering any question of the reform of the subject; to know the early geometric methods of solving equations is necessary if one would appreciate several improvements in teaching which are now being advocated; and to know the early story of the calculus is equally important if we would rescue the subject from its present unhappy status. These are but a few illustrations of the innumerable lessons which history has for the teaching (not to speak of the developing) of the subject.

And finally, after the student knows the science, its history and its applications, at least one year of professional training in the teaching of mathematics is necessary. In this the successes and failures of the masters should be made known to him, encouraging him to do better work, and warning him against well recognized dangers. He should get, what so few teachers have, and what mere academic instruction does not bring, a knowledge of a teacher's library, of the world's best textbooks, and of the literature which appeals to the pupil. There should also be brought before him the best methods of treating typical chapters, the possibility of improving the sequence, and the important question of the interrelationship of the branches of mathematics and of their contact with the other sciences and with the life about us. If we are to effect the reformation in algebra that has been effected in arithmetic, if we are to vitalize our applications of equations, if we are to modernize our geometry along the recent French lines, if we are to put trigonometry where it belongs and teach it as something to be used, and if we are to work out the various other problems of similar nature that are at this time pressing upon us for solution, it will be possible largely through the efforts and cooperation of that earnest body of workers which is constantly increasing by the advent of college graduates with a broad professional training. For such a body of workers the school has great need. Never has there been such a seething period in the educational world. The questions of the improvement of the teaching of mathematics are no longer local, no longer national; a reform in Italy is known at once in America, in New Zealand, and in that eastern island empire whose recent success in the field of battle and on the seas is paralleled by its advancement in education as well. To keep pace with other countries, to take what we can use and reject what is not suited to our needs, and to keep pace with the demands of science, of engineering, of commerce, of labor and of finance — all this lays heavy demands upon the gild of mathematics teachers, and the proper training of apprentices who would enter that ancient and honorable order may well command the interest and the thoughtful cooperation of an association with the ideals this one so carefully guards.

SCIENCE TEACHING SEEN FROM THE OUTSIDE

BY EDWARD L. THORNDIKE, TEACHERS COLLEGE, COLUMBIA UNIVERSITY, NEW YORK CITY

What I have to say about science teaching is, as the title clearly states, the contribution of one whose duties do not lead to direct personal acquaintance with the process of teaching physics or chemistry or biology, of one who can speak only as an outsider. I trust that great interest in the teaching of science, a sure conviction of its importance in schools, some study of the application of general principles of education to the aims and methods of teaching of science, and the fact of being a student and teacher of one of the other sciences, may be accepted in lieu of specific expert knowledge.

To such an outsider, interested primarily in science teaching as one fraction of our total educational endeavor, it is easiest to think of it according to the ways it fulfils the three functions of utility, discipline and culture. I hope to present facts concerning each of these three functions which will not be wholly trite and which may be deserving of serious thought. It would obviously be ridiculous to attempt any adequate or balanced discussion. A series of statements of facts which you, just because you are specialists in teaching physics or chemistry or biology, may have overlooked and which I have, in some semipsychological studies of education, been particularly attentive to, will be much more profitable.

It is fashionable for those who speculate about education and to a less degree for those who actually teach, to decry utility as an end of the study of science in the lower schools. At the very same time in the higher schools, in our university courses in chemistry, in our medical school courses in physiology, in our engineering school courses in physics, we frankly admit the value of so teaching science that the student may have greater productive power as a worker. Moreover in the lower schools, although we might be ashamed to teach physics so that the boy or girl would be by it better fitted for the semiscientific trades and industries, we inconsistently make the preparation for the utility courses of the college, technical and professional schools a main feature of the work. Now the fact which you are likely to forget is that the high school is far more frequently a school preparatory for life than a school preparatory for later schools. Of the students in a first year high school course in physics or chemistry, for instance, not 5 in 10 are to be prepared for any further work in science at all, for not

5 in 10 will ever take another course in science. Hardly more than 1 to 10 are to be prepared for college or other higher institutions, for the good and sufficient reason that they won't go to any such. Only 1 in 4 will even stay through to the fourth year of high school. Not 1 in 200 is to be prepared to become a scientist. But they are all to be prepared to live. The science useful to a parent, the science useful to a citizen, the science useful to a housekeeper, the science useful to a worker in business or technical industry — any one of these is a more important topic to you than the science useful for college entrance.

The watchword of high school education for the last half century has been mental discipline. Realizing the meagerness and inappropriateness of the culture given by the linguistic and mathematical gymnastics, their advocates were fond of asserting that they in mysterious ways taught the mind to think better and act more wisely in any of life's problems. Though you forgot what you learned your memory had been strengthened; though you lost all interest, your will power had been increased; though you never utilized your conclusions, you had learned to reason. Science teachers in self-defense stole the enemy's thunder and declared that science, too, was to be taught, not for the information, but for the discipline which it gave. It became fashionable to assign a relatively small value to acquaintance with the facts and laws of science, and to direct teaching to habits of accuracy in observing and recording phenomena. As a consequence courses were occasionally designed which were nearly as barren of any important knowledge as the traditional exercises of the first year Latin book. Wires were measured whose lengths meant nothing of consequence to any one; thermometers were read for no purpose except to read them; trivial details of animal structure were painfully examined and elaborately drawn for observation's sake alone.

The unfortunate thing about such practice is that such a seeking to save the disciplinary value of science is precisely the way to lose it. The investigations of the influence of any form of special training in giving general ability, show that improvement due to practice with one set of data is confined rather closely to those data and that the more specialized the data are, the more remote from and unlike the ordinary situations of life they are, the less will the improvement spread beyond them. Even for disciplinary value alone, the study of important facts, general laws, the real stuff of scientific truth is far better than the study of trivial features of natural objects, be that study never so refined in its methods.

Moreover, the whole notion of mental discipline in science study and elsewhere needs revision. The traditional notion, or superstition, that doing one thing well in some subtle way makes one able to do everything else much better is certainly false. Any method of teaching which has no other raison d'être than its supposed disciplinary effect is almost surely questionable. One special study fits for all life in proportion as it fits one to handle certain data which recur again and again in life and in proportion as it develops ideas and ideals of method which are applicable over wide areas of life. From the disciplinary point of view the business of science teaching is to select for study those aspects of experience which are frequent elements in life's problems and to arouse in one or more fields of experience and apply to many more the ideals of open mindedness, of observation of actual facts, and of constant verification by facts which are the essence of science. To prosecute this business most successfully one needs to seek, not to avoid solid scientific information. We should not experiment and verify for the sake of experimenting any more than we should read Shakspere or the Bible for the sake of learning how to read.

The distinguishing feature of scientific teaching, and the feature on which you justly congratulate yourselves, is the limitation of work with words in books and the addition of work with real things in museums and laboratories. The progress of science in and out of schools has been on a road leading away from books. Progress along this road will and should continue and increase. But to an outsider at least some teachers of science seem to miss the real justification of laboratory work. You will agree, I am sure, that the value of laboratory work is chiefly that the student must learn realities if he learns at all, and must or at least may verify results, whereas lessons from books may issue in nothing but words and discourage verification. A less but still a high value attaches to the personal contact with a variety of practical problems in managing time and effort in the independent conduct of experiments. It is not simply being in a room with tables and fingering apparatus instead of being in a room with desks and thumbing books. Complicated apparatus may conceal reality quite as successfully as words do. Washing test tubes is no more scientific than turning leaves. Brass and glass, rubber tubes and iron clamps need be no more educative than ink and paper. A drawing may express less than an oral recitation. A laboratory is not a place where you spend two hours of manual labor to find out something you could learn better in two minutes' reading. To have students manipulate instruments for the sake of manipulation is like making English composition a series of exercises in penmanship.

Any laboratory is well conducted which teaches students the real facts of the world of nature and forms the habits of verifying one's notions about them by experiment. No teacher need feel that his laboratory instruction is in any way weak, so long as his students learn science and answer proper questions correctly by themselves experimenting and verifying. Conversely no array of instruments and notebooks, and no perfection of organization can be satisfactory if the students are not made thereby to know science and to be scientific.

I referred a few moments ago to the fact that in our experimental studies of training in observation and inference we find as a rule that the more valuable the content, the stuff observed, the inferences drawn, the greater is the disciplinary value also. I venture, with less assurance, the corollary that the efficiency of that observation itself is as much a function of correct knowledge about nature as of a habit of direct observation of objects. No matter how interested and impartial a student is, he can not make fully successful observations of diseased throats unless he knows that the Klebs-Loeffler bacillus is the cause of diphtheria, that membranous croup is diphtheria, and that certain facts are the characteristics of that bacillus. It is not only an experienced and just and exact eye that an observer of the solar system needs, but also information about the spectroscope. A careless and absent-minded man who knows the facts of organic evolution, Mendel's law, and the theory of measurements of variable phenomena, may do better in observations of heredity than a very cautious and skilled recorder of shape and color of Lamarck's day could do. It has been a silly fashion in pedagogy that has decried new knowledge. The weaknesses and errors which have been laid at its door are almost without exception such as belong only to knowledge of words. Knowledge of things, or reality, is always harmless. It is of enormous value when used by an intellect of first-rate capacity. It is the essential gift of education just as capacity is the essential gift of nature.

The most important disciplinary effect of science teaching is the habit of verification. This is something which science teaching can give, which is unlikely to come in any other way, and which ay transform a student from a stupid or clever source of guesses into a successful thinker. Nature, even to the intellects of high capacity, rarely gives more than the capacity to get such ideas as the physical and social environment offers and to eliminate from influence on practice those ideas which too violently injure the individual and the species. Its progress in the latter action is excessively slow. The mere function of having ideas puts man so far superior to other species that he has become almost invincible even though bearing an enormous burden of ignorance, supersition and folly. Human reason, though used, as Professor Cattell has said it still is, in much the same aimless manner as a child uses a toy, is sufficient to maintain human supremacy.

This slow and limited advance by natural selection can be accelerated by an artificial selection for preservation of only those ideas which correspond to reality, which correctly prophesy the future, which are verifiable by fact. The goal of mental evolution can be made infallible insight into and control over nature and ourselves, instead of merely enough wisdom to keep us alive. Every parasite and bacterium can be exterminated from the world as fully as wolves have been from Westchester county, or domesticated to human service as the sheep or cow.

It may seem as if thought could be sufficiently well guided in the making, as if we could so arrange circumstances that we could know beforehand that the conclusions would be true, as if by the control of observation and inference, the right variations in thought could be surely created, with no need for selection among them by verification. But in point of fact, as the experience of the world of thought inside and outside of school shows, we make less progress by directing thought beforehand by sufficiently proper methods than by correcting it afterward by its adaptation to reality. Both logic and experimental verification are necessary. As in nature, we must not only stimulate variations in certain desired directions but also select rigidly those which turn out to actually be in that direction.

Indeed, the highest duty of science teaching is to show the possibility of verifying by observation and experiment any notion concerning any matter of fact, the student really doing it in cases where it is practicable, to enforce the rationality and morality and practical need of it, and to encourage that holy impatience with any unverified ideas which is the specific distinction of the scientific mind.

The practical consequence of my eulogy of verification is of course that in all science teaching we should remit somewhat of our elaborate arrangements to control the process of getting ideas and use the time and energy thus saved to insure that the ideas be more often verified. Are we not perhaps too afraid that the student of chemistry will get his ideas from books or from us instead of from his laboratory experiments? I confess that to my mind an idea learned from a book but tested by an experiment is better than an idea learned from an experiment but left unverified. There is indeed a very strong argument to be made for opening every door to knowledge, even to decent guesses, as wide as possible, provided only the knowledge or guess be sooner or later tested by the student in every practicable case.

There is probably no need for me to make any comments on the cultural side of science teaching. I venture, however, to encourage the faith which I trust each of you possesses that in the intellectual heritage which the past gives to the present, the share of science is the largest and also the best. The trade of poet or scholar or literary man or painter is no more happy or intellectual or noble than that of scientist. No human want is higher than the want for truths. No human act is better than the search for insight into nature whereby it is controlled for the welfare of men.

The study of human life in literature and history and of the great ideas of the past concerning our nature and duty and destiny may be in its topic a more important contributor to culture than the study of the physical world, but in its methods it is less so. Moreover, in proportion as the methods of science are applied to the problems of human behavior, the so called humanities will become science and their culture value will increase. It is not the fiction in literature and history that is cultural, but the truth. The culture which is needed in modern life concerns only the truth, the truth concerning man and his social relations as well as the truth concerning his physical surroundings, the truth discerned by the wise of all ages as well as the truth newly achieved in our laboratories, but always the truth. This culture, found in the study of the sciences of nature and of man, it is the function of the teacher of science to give.

SECTION MEETINGS

Thursday morning, December 27

Section A — PHYSICS AND CHEMISTRY

THE NEW MOVEMENT FOR THE REFORM OF PHYSICS TEACHING IN GERMANY, FRANCE AND AMERICA

BY C. R. MANN, UNIVERSITY OF CHICAGO

One of the most important, promising and inspiring features of the present educational turmoil is the agitation that centers about the teaching of science. The importance of this agitation lies in the fact that many of those educators, who have studied the whole educational situation most deeply, have concluded that present conditions offer a problem whose solution will not be finally reached, until science has been placed in the central position which she is certain to occupy sooner or later in the educational system.

The promising part of this agitation appears when we consider that the latent powers of science as a means of educating men in their modern scientific environment have not been hitherto fully recognized, much less realized in practice.

The inspiration in the present situation is derived from the combination of the conditions just set forth: for since education is famishing for the fruits of a new method of teaching science, and since science offers a most fertile, though uncultivated, vineyard in which such fruits may be grown, is there any teacher among us who is not inspired to enter into this vineyard at this dawning of the new day, and to labor diligently for the production of the fruits thereof?

If those of us who elect to enter this tempting vineyard to toil for the production of the new fruits would have our efforts rewarded with a rich and plentiful crop, we must at the outset recognize the fact that new methods of husbandry are demanded by the new conditions under which we work. We must comprehend at the very start that these new fruits will not grow, as the older ones did, in a soil that has been fertilized with the bones of dogmatism and of memory drill. For, just as science itself could not grow as long as the European mind was steeped in a reverence for opinions and for authority, so science teaching can not develop effectively if it follows didactic and authoritative methods.

This fundamentally important distinction may, perhaps, become clearer if illustrated by an example taken from that admirable little book by Mrs M. E. Boole, on *The Preparation of the Child for Science* [Oxford, Clarendon Press]. We there read [p. 22]:

> In classical learning it is eminently desirable to secure that the right impression shall be made from the first; that wrong impressions shall have as little time as possible to deepen themselves. We wish the child's eye and ear to become accustomed from the first to welcome the right and reject the wrong; we do not wish him to gain the habit of tolerating wrong impressions. If the child uses the nominative where he should use the accusative, and is not at once corrected, that is so much to the bad for his future progress; if he can be got not to be able to remember a time when he used the word wrongly, that is so much to the good. But in science there are, there can be, no absolutely right impressions; our minds are not big enough to grasp any natural fact as a whole; everything depends upon drawing right conclusions from combinations of impressions, each of which is in itself inadequate and partially misleading; and if the pupil is to be got into scientific methods, that is what he must be trained to do. In order that he may learn to do it, it is sometimes necessary that a succession of "wrong" impressions should have time to register itself on the brain and become part of its available stock. Such a statement may naturally convey to the scholastic mind trained in classic traditions an impression of disorderliness, but it does not imply disorder. Up to dateness is the cause of disorder; the haste, the greed, to efface rapidly each partial impression, when we have nothing to substitute for it but some other impression equally partial, is not only unscientific, but eminently disorderly.

In the light of these remarks it is easy enough to understand why we have attempted in the past to teach science dogmatically. Languages and mathematics and history were so taught: languages and mathematics and history were the only subjects in the curriculum; therefore, all things should be so taught. When we science teachers ourselves came to teach, the habit was upon us, and so we taught that way by habit.

Under such conditions we can not blame the public for still clinging to the old conception that the classical education was and is the only broadening one. Those methods of teaching were suited to the classics; for the sciences, those methods were and are an abominable misfit. So it is not surprising that the results obtained when those methods were applied to the teaching of science were and are and always will be highly unsatisfactory. Until we learn that science is not classified knowledge — a thing to be learned by memory — but rather, that science is the classification of knowledge, a living process that can only be mastered by constant, careful, and watchful exercise in its use, we can not expect that the teaching of science will advance into the prominent position that is now awaiting it in the educational world.

Nor is the day far distant when science will enter into her heritage. For the past six or eight years she has been gradually waking up to her opportunities. This awakening has not been confined to any one limited locality, but has been taking place simultaneously in Germany, France, and America. It is the purpose of this discussion to call attention to the signs of this awakening as manifested in reference to the subject of physics in these three countries. As we proceed, it will appear that, although the course followed by this agitation in each of these countries has differed in detail from those followed in the others, yet the fundamental principles that have guided all three are the same; namely, those that have been explained just now in their general outline.

In Germany the reform movement began formally on November 26, 1900, when the minister of education, with the approval of the Emperor, decreed that henceforth the schooling given in each of the three types of German secondary school should be recognized as of equal educational value by the government. The courses in these three types of school correspond roughly to those that lead in this country to the degrees of B. A., Ph. B., and B. S. respectively. This decree of the German government had the effect of effacing, at least officially, that subtile and elusive sentiment which clings to the classical course as the only means of securing a really broad and cultural training.

The first feelings aroused by this edict among the German teachers of science seem to an outsider to have been those of surprise mingled with delight. At any rate, these teachers at once began to look about them to see if it were really true that science had the power of giving an education that was truly cultural. The first active movement on the part of the scientists came from the biologists, who, at a meeting of the German Association of Natural Scientists and Physicians, held at Hamburg in 1901, brought forward a set of theses in which were enunciated the principles whose application would place the teaching of science in the position accorded it by the imperial decree. These theses are now known as the Hamburg theses. They were widely circulated among science teachers in Germany, received the written approval of some 800 of these teachers, and were formally unanimously approved by the association at its meeting in 1903.

The first five of these theses set forth the fundamental principles of the new method of science teaching — the method that is to give to the teaching of science its cultural value. They were written to meet the special case of biology, but apply equally well to all the sciences. When worded so as to include the other sciences as well as biology these theses read:

1 Natural science is founded on experience, and it extends to the limits of our cognition of natural phenomena, but no further. As science, it is not responsible for metaphysical speculation and believes that such speculation has no place in the secondary schools.

2 Formally, instruction in the natural sciences is a necessary complement of the abstract subjects. In particular, science teaches the art, otherwise so neglected, of observing concrete objects in process of continual change, and proceeds inductively from these observations of properties and processes to the logical formation of concepts.

3 As to content, instruction in the natural sciences should make the growing youth familiar with the most essential and typical processes in the world about him, should describe the phenomena of life in their complexity, should make clear the relations of inorganic and organic nature to each other and to man, and should give a summary of the most important periods of the history of science.

4 Ethically, a study of the natural sciences should awaken a respect for the creations of the world about him — a perception of the beauty and the completeness of nature as a whole, and thus should become a source of pure delight, untouched by the practical interests of life. At the same time the occupation with the phenomena of living nature should lead to a conception of the limitations of human knowledge and to a simple modesty.

5 Such a knowledge of the world about him must be regarded as an essential part of the culture which the times demand: it is not only useful to the future scientist or physician by making his entrance into his profession easier; but also, in like manner, it is useful to those graduates of the secondary schools whose later work does not directly require a study of nature.

Would that there were time for a full discussion of these theses! Since they contain the essence of the new method of teaching science, they should be studied carefully and pondered well by every one who wishes to bring his teaching into line with the new movement. But we must proceed. The adoption of these theses in 1903 led to a full discussion of the subject at the next meeting of the German Association of Natural Scientists and Physicians in Breslau in 1904.

As a result of this discussion a commission consisting of 12 members was appointed to consider what might be done to bring about practically the desired results. This commission began its work in December, 1904, and has issued two reports.

The first of these reports was presented to the Association of Natural Scientists and Physicians at its meeting in Meran in September, 1905. This report is worthy of extensive study even here in America. An English translation of it is being prepared and will, it is hoped, soon be ready for publication. The first part of the report deals with general conditions. It first explains how the commission has endeavored by widespread distribution of its documents to obtain as broad a discussion of the principles involved, and also to gain as much support for those principles as was possible. It was their aim to get every individual to express his opinion freely and frankly, and to include in the report only those suggestions on which there was practical unanimity of opinion.

Then follow three general principles which are stated as the platform of the commission. These are:

1 The commission desires that the education given in the secondary schools be neither one-sidedly historical and linguistic nor one-sidedly mathematical and scientific.

2 The commission recognizes that mathematics and the natural sciences furnish educational material that is fully equal in value to that furnished by the languages. It also adheres to the principles that general culture is the specific aim of the secondary school.

3 The commission declares that the enjoyment in fact of equal rights by the three classes of schools is absolutely essential, and wishes that this may be completely realized.

The remainder of the report is taken up with a discussion of the conditions of the schools and with recommendations as to the number of hours to be devoted to each science, together with a recommended outline of each course and of its method of presentation.

Several points in this discussion are worthy of particular notice in passing. Thus, difficulties were encountered in finding a sufficient number of hours for the science work in the classical courses, without curtailing those devoted to ancient languages. They have as yet been unable to deal with this situation in a manner satisfactory to themselves. They remark: "The commission stands firm in its position that at least as much science study as is outlined in the courses herein described is absolutely indispensable for a complete and well grounded understanding of our modern life." And again:

"Since this (reduction of the hours devoted to the classics) could only be obtained by the cooperation of a number of different factors, the commission can do nothing but emphatically point out the existence of a yawning chasm in the scientific training given by those schools."

Another important point in this report is that the commission declares emphatically "that an extensive freedom for the teacher in selecting details both of subject-matter and of method of presentation within the outline of the course is essential."

In the special report of physics, the commission declares itself in favor of increasing the time allotted to this subject, "in order that it may be possible to attain fully the educational value of scientific study, at least in this one branch of science." The time demanded for physics is three hours a week for the last five years in school. In comparing this time allowance with that given in America, we must remember that these five years would extend in our system about to the end of the sophomore year in college.

As to the purposes of physics teaching and the methods of presenting the subject, the commission makes the following statement [First Report, p. 21]:

> The instruction in physics should not only impart to the student a number of single bits of information that are applicable to his life and lead him to a correct use of his senses and to a true description of what he has perceived, but it should also lead him to gain an insight into the well ordered relationships among natural phenomena, and should teach him to understand the methods by which such an insight is obtained. A physics teaching that has this aim will develop in the students, in addition, the ability of forming apt judgments concerning real relationships, and will thus furnish an intellectual training that can not be replaced by any other, no matter what their future life's work may be.
>
> The specific value of physics teaching for general culture has for a long time been seriously impaired by the fact that the subject has been presented as a mathematical science. The most important reason for this condition of affairs lies in the fact that physics itself has always held to the ideal of being presented in deductive form in the manner of a mathematical demonstration. This is particularly true of the most fundamental portion of physics, namely, mechanics, whose ability to be built up on a few axioms has been considered to be very much to its advantage. Also the mathematical formulation of numerous physical laws has helped to support this conception. In addition, the tendency has been to place the teaching of physics in the hands of teachers who are primarily mathematicians; and besides, in the examinations of teachers, until recently greater weight has been laid by the examining boards on a knowledge of mathematical physics than on the experimental work.

In opposition to this unfortunate attitude, a very different idea has recently been gaining rapidly in favor, and we place this notion as the first fundamental principle at the beginning of our recommendations concerning the methods of teaching physics. It is: *For purposes of teaching, physics must be presented as a natural science and not as a mathematical science.*

This principle implies that the teaching shall, as far as is at all possible, begin with the consideration of those processes that are actually taking place in nature; and it must lead to an understanding of the phenomena of the lifeless and living nature about us.

On the other hand, an injury, no less serious than that resulting from a one-sided mathematical presentation, may be done to physics teaching by the directly opposite mistake of crowding aside the thinking out and the mental absorption of the subject, by the presentation of numerous brilliant experiments. Under these conditions it is hard to prevent the teaching from resulting in the amassing of a large number of single bits of information, whose apparent systematic arrangement is no compensation for the lack of inner unity. Hence the second fundamental general principle is this:

For the purposes of teaching, physics must be presented in such a way that it may serve as a pattern of the method by which knowledge is acquired at all in the domain of the experimental sciences. Physics is especially adapted to be used for this purpose; since it has the advantage over the other branches of instruction, because in it application is made of the most exact methods of acquiring knowledge to the simplest conceivable materials.

From this it follows that the teaching should be done largely by the heuristic method. The instruction should begin with the consideration of such problems as have already arisen in the mind of the child because of his thoughtful observation of phenomena, and which appear in increasing number as the investigation progresses. The art of the teacher will consist, for the most part, in arranging these problems in order, holding some in the background and bringing others to the front of the discussion, in order that there may be uniform progress all the time toward a more comprehensive knowledge.

It is not sufficient that the pupil see the experiments only at a distance as they are performed on the lecture table in the lecture room. Even under the most favorable conditions it is not possible to obtain in this way more than a partial grasp of the processes illustrated . . . Hence to the other principles we would add a third, namely,

For the development of the pupils in physics, systematically arranged exercises in personal observation and experimentation are necessary.

The remainder of the report is taken up with outlines of proposed courses in physics and the other sciences, together with instructions for the use of the outlines. For further information as to the details, the original report will have to be consulted.

A second report was presented by the commission to the German Association of Natural Scientists and Physicians at its meeting held in Stuttgart in September 1906. This report has just been published. In it attention is first of all called to the fact that the reform for which it is striving is not a superficial change which applies to Germany only. It is shown to be due to "deeply flowing currents which have taken hold of nearly all the cultured peoples in the same, or in very similar ways . . . With the recognition of the international character of these new efforts in education, comes the deeper insight into the magnitude of the questions that have been raised with regard to the well being of our entire nation, and to its future, from both the ideal and the practical points of view . . . Recognizing the tremendous difficulty which must be overcome in carrying out all our desires, we must say: 'This undertaking is both serious and full of responsibility for those who have been called to steer the ship of education, so that it may pass, without injury to the youth intrusted to it, over the dangerous shoals and past the frowning headlands on to the safe harbor of a culture suited to the spiritual, social, and physical education of the present day.'"

The commission then reiterates its desire to refrain from the discussion of details, and of directing attention to the broader problems of science teaching, leaving the details to be worked out by each teacher in conformity with the conditions in which he is placed. The remainder of the report deals with the conditions and the curriculums of several other types of German school, and works out for them the application of the general principles for which it stands.

It is as yet too soon to know what the results of the work of the German commission will be. Certain it is, however, that they have brought clearly and effectively before the German school authorities the necessity of certain fundamental changes in the methods of teaching science, and have outlined the general principles that must guide them in making those changes. They have also shown, somewhat in detail, how those principles may be applied in practice. It now remains to be seen what use the schools will make of the valuable suggestions that have been laid before them.

In France, the course of the reform movement has been very different. There the government is much more intimately connected with the school system, and so the first official actions in the movement came from the ruling bodies. Unfortunately I have not yet been able to trace the causes for these governmental decrees concerning education, and to find out what the conditions in the schools were before the issuance of these decrees.

In January 1902, the French Minister of Public Instruction sent a letter to the president of an educational commission of the French Chamber of Deputies. In this letter were set forth at length numerous proposals for changes in the national system of education. The suggestions contained in this letter were approved by the commission, and reported to the Chamber of Deputies. That body approved the report of the commission on the 4th of February 1902, and the recommendations of the report were then issued as a national decree by President Loubet on the 31st of May 1902.

The first part of the report of the commission of the Chamber of Deputies deals with the administrative reorganization of the school system. To an outsider, the interesting point in this discussion is the agreement to grant but one bachelor's degree, whether the course pursued was the old time classical course or the modern scientific course. This action, it will be noted, is exactly parallel to that of the German government in recognizing the equality of the three types of German school.

Subjoined to the discussion of administrative reorganization, are the official programs of the courses. Physics appears in these programs in the year that corresponds to our first year in the high school. It is required for two hours a week for two years, and then for three hours a week for two years, and finally for five hours a week for one year in the scientific course. In the classical course it appears as a requirement of one hour a week for four years, and then three hours a week for the last year, which, as in Germany, corresponds roughly to our sophomore year in college. For the science courses therefore, the time allotted to physics is the same as that in Germany, namely the equivalent of five hours a week for three years.

Since this discussion is concerned mainly with the pedagogical side of the situation, we will not stop to analyze the courses, but merely note the advice given to the teacher, as to the methods of presentation. At the end of the program for the first year's work in physics is given the following general advice to the teacher:

> The teaching of physics in the first year should be kept very elementary and of a practical nature. It must always be founded on experience. In his demonstrations the teacher should avoid as much as possible the use of complicated apparatus; he should on the contrary endeavor to carry out his experiments with ordinary objects. He should make use of graphical representations often; and

he should try, by means of numerical applications taken from actual, real cases, to accustom the pupils to take account of the relative order of magnitude of phenomena.

When we come to the third year of the high school, the advice to the teacher is changed. In this year he is told:

> The teacher should content himself with describing the facts as we know them today, without paying too much attention to the historical order. He should free his teaching from many of the antiquities which tradition has preserved, such as superannuated apparatus, theories without interest, and calculations without reality. He should not enter at all on the minute description of apparatus, nor on the methods of using it. The purpose of the course is not to make professional physicists of the pupils; but rather to bring them to recognize the larger laws of nature, and to make it natural for them to take account of what is going on about them. With this in view, the teaching should be at the same time very high, very simple, and very practical. Mathematical developments should be avoided, and the discussion always based on experience. In his experimental demonstrations he should use the least possible amount of complicated apparatus, and should seek to realize his ends with the most simple means and those that are most readily at hand. He should attach much more importance to the spirit of the methods used, than to the technical details of manipulation. He should frequently use the graphical method of representation, not only for the sake of showing the pupil more clearly the relations between phenomena, but also for the sake of making those most important ideas of functionality and continuity penetrate into their minds. Finally, by means of numerical examples, which are in every case taken from real cases, and which are reduced to their simplest forms, he should accustom the students to take account of the order of magnitude of phenomena, and to be able to see within what limits a correction is either necessary or absurd.

As has been stated, the new courses were adopted by the national government in 1902. In 1904, the subject of teaching science in the secondary schools was chosen for the conferences of the Museé Pédagogique. This Museé is a government institution quite similar to our Bureau of Education. In it are kept all documents concerning education, and the statistics of the schools. It possesses one of the finest libraries in the world on the subject of education. But in addition to being a storehouse of documents and statistics, the officers of the Museé have recently undertaken to conduct some important conferences on educational subjects.

At the first of these conferences, which was held in 1904, some very important and suggestive addresses were given by some of the most illustrious French scientists and educators. A brief summary of the principal points touched in these addresses follows.

The first address was given by Mr L. Liard, vice rector of the Academy of Paris. He said:

When the director of the Museé Pédagogique informed me of his intention of organizing here some conferences on the methods of secondary instruction, I heartily indorsed the plan, and urged him to begin with the sciences.

It seemed to me that this subject was the most pressing; for the new outlines of studies have definitely assigned to the sciences their true function in secondary education. In spite of many good intentions, they have hitherto been treated merely as materials for entrance examinations. They may now become instruments of culture.

In secondary education, the scientific studies ought, like the others, to contribute to the development of men. Their proper duty is to work toward the cultivation of everything which is of service to the mind in discovering and understanding positive truth — observation, comparison, classification, experiment, induction, deduction, and analogy. They should also arouse and develop that sense of reality which is no less important than the spirit of idealism; so that they would become, in a quiet but efficient manner, the masters of philosophy: they should drill the mind into the habit of not thinking by fragments, but of understanding that every fragment is but a part of some great whole.

In order to fulfil this mission, it is evident that the teaching of the sciences ought to appeal especially to the active faculties of the mind,— to those same faculties by means of which science has been built up. The memory plays in this a certain part, but not the principal one. Memory can do nothing but retain. Nothing can be more at variance with a true teaching of science, than to cram into passive minds a mass of abstractions and of facts to be learned by heart. What should be done, on the contrary, is to arouse the spontaneity of the student, to set his mental activities going,— in a word, to make him capable of action. In this, as in other things, the real value does not lie in what the student can reproduce, but in what he can produce.

He then points out how, in the past 20 years, the mathematicians have passed through a state of transcendental idealism, in which they have entirely lost sight not only of the earth, but also of space. While this sort of thing has its place in the higher education, it is certainly out of place in the secondary school, where we are not trying to prepare members of the Academy of Science, but to develop clear minds which see distinctly and reason correctly.

Passing to the subject of definitions, he questions the value of starting a subject with purely nominal definitions, and of filling the student's head with symbols, before he comprehends the meaning of the symbols, and has clearly in mind the realities to which they correspond. On this point he says:

> In general a child but little understands definitions and abstract formulas. Doubtless he can recite them, just as he can repeat words of an unknown language, by imitation. What is immediately accessible to him is the concrete; hence the greatest service that can be rendered him is not to throw him at a single bound into the abstract, but to so direct his work that he enters it himself.

Finally, in regard to the method of presentation of the subject-matter, he says:

> By the method of presentation, the sciences, instead of appearing experimental and inductive as they really are, are developed deductively. First a law is stated as a theorem; then the demonstration is given, always as if a theorem were being treated. The fact does not appear till the end, and when it appears, it is brought in as an illustration and not as the source of the law. When an experiment is presented, it is generally at a distance, so that it serves merely as an aid to the memory, by associating an image with a formula. As a matter of fact, the experimental sciences develop in just the inverse order. The physical sciences should, therefore, be made experimental and inductive, so that they would appeal at the start to the facts, and would thus accustom the student little by little to see for himself how the laws are derived from the facts.

This address by Mr Liard was followed by one by Mr Henri Poincaré, professor of physics at the University of Paris. As is well known, Mr Poincaré is the leading physicist in France, if not in all Europe. His subject was The General Definitions of Mathematics. The following quotations may serve to give some idea of the main points in his paper:

> What is a good definition? For the philosopher, or the expert, it is one that applies to all the objects defined, and to no others; it is one that satisfied the rules of logic. But in teaching, it is not that; a good definition is one that the pupils understand. . .
>
> For example, we are in a high school class; the teacher is dictating "The circle is the locus of all points in a plane which are equidistant from a fixed point called the center." The good pupil writes this phrase in his notebook; the poor pupil draws therein pictures of good men; but neither of them understands. Then the teacher takes the chalk, and draws a circle on the blackboard. "Ah!" think the pupils, "Why did he not tell us at once that a circle is something round, and we would have understood him?" Doubtless it is the teacher who is right. The pupils' definition is valueless, since it can not serve for demonstration purposes, and especially since it could not give them the healthy habit of analyzing their concepts. But it would be better to show them that they did not understand what they thought they understood, and to lead them to acknowledge the

crudity of their first concept, and to desire of themselves to improve it and make it less crude. . .

I have introduced this example in order to bring out clearly two opposing concepts between which there is a marked contrast. This contrast is explained for us by the history of science. If we read a book written 50 years ago, the greater part of the argument which we find there seems to us to be devoid of rigor. For example, at that time it was admitted that a continuous function can not change sign without passing through zero: that it can do so has been proven today. They then trusted in intuition; but we have come to see more and more clearly that intuition can not give us rigor, nor yet certainty. And as we came to demand certainty, it was necessary to allow intuition to play a less and less important part. . .

How was this necessary evolution accomplished? We were not long in finding out that rigor could not be obtained in the argument, unless it was introduced at once into the definitions. For a long time mathematicians worked with objects that were badly defined. They thought that they had clear concepts, because they could represent the things to themselves either in models or in imagination; but they had but crude images and no precise ideas on which an argument could be constructed. Here then was the place for the logicians to apply their efforts. The result may be seen in the idea of incommensurable numbers, for example. The idea of continuity which we have by intuition has been resolved into a complicated system of inequalities relative to whole numbers. In this way all the difficulties that bothered our fathers when they reflected on the fundamental facts of the infinitesimal calculus, have disappeared. . .

But do you think that mathematics has attained this absolute rigor without making some sacrifice? Not at all; for what has been gained in rigor has been lost in objectivity. It is by withdrawing from reality that this perfect purity has been acquired. . .

Mr Poincaré then proceeds to show to what lengths this hunt after rigor has led the mathematicians, and points out how this development of the purely logical side of the subject has led to the invention of a crowd of "bizarre functions which seem to resemble as little as possible the honest and practically useful functions and which have been invented solely for the purpose of showing the faults in the arguments of our fathers." These functions seem to be more general than the useful ones, he claims; and hence, if logic were the only guide in matters of teaching, these functions should stand at the head of the subject. Yet if we were to do this, as logic demands, and set up for the argument premises that seem to the students less evident than the conclusions, these unfortunate beings will think that mathematics is nothing but an arbitrary stringing together of useless subtilties; they will either lose their taste for it, or will play with it as if it were a game, and arrive finally at a state of mind similar to that of the Greek sophists.

> The chief aim of mathematics teaching is to develop certain faculties of the mind, and among these intuition is by no means the least valuable. . . Demonstrations are constructed by logic, but inventions are made through intuition. To know how to criticize is good; but to know how to create is better. Logic teaches us that on such or such a path we are sure to meet no obstacles; but it does not tell us which path it is that leads to the goal. In order to find this out, we must see the goal from a distance, and the faculty that enables us to do this is intuition. Without this, the geometer would be like a writer whose attention was riveted on the grammar, but who had no ideas.

Having thus shown the opposing needs of logic and of intuition, he proceeds:

> Is it possible to satisfy these opposing conditions, in particular, when it is a matter of giving a definition? How can we find a concise statement which will satisfy at the same time both the inviolable rules of logic and our desire to comprehend the place of the new notion in the ensemble of science,— our need of thinking with images? Generally a way can not be found, and that is why it is not sufficient to simply state a definition; it must be prepared for, and it must be justified. . . The best way of doing this, whenever it is possible, is to let the justification precede the statement and prepare the way for it. The general statement should be approached through the study of several particular examples.

Having thus established the principle of the justification of a definition before its statement, he gives in the remainder of the paper a number of examples, in which he shows how this principle may be applied in various cases. Passing over his suggestions concerning mathematics, we may glance at his suggestions with regard to mechanics. He says:

> How shall we define force? That a good logical definition does not exist, I have shown clearly elsewhere. The anthropomorphic definition, derived from the sensation of muscular effort, is too crude, and nothing of value can be deduced from it. This is the course I would follow: I would show one after another all the species of this genus; they are numerous and very diverse. There are the pressures of fluids on the walls of the vessels that contain them, the tension of threads, the elasticity of springs, weight, friction, action and reaction between two solids in contact, etc.
>
> This would be but a qualitative definition. It would then be necessary to learn how to measure force. To do this we must show that one force can be replaced by another without disturbing equilibrium. We should show that we can replace a weight, not only by another weight, but by different forces of nature. Etc. From this the idea of the equivalence of forces is built up.

He then advises the experiment showing that one force may be replaced by two forces in the same direction, and that the sum of the two is equal to the one, and leads up, by gradual steps to three or more forces in a plane. His final conclusion is:

> All this is experience, and experience is the only thing that can teach us. It will be sufficient to mention several common experiences, which all the students have every day, and to execute for them a few simple experiments that are well chosen.

In the syllabus that was submitted to the physics teachers in circular IV of the New Movement, this suggestion of Mr Poincaré's has been carried out in the first sections. The entire address is one of extraordinary interest, and will repay a careful study. The same is true of the others in the series given at this conference. It would be well worth while to outline them in as great detail as has been done with this one. But this is out of the question in our limited time, so I will merely indicate the most important point in each, and refer you to the original for the complete argument.

The principal point in the second address, which was given by Mr G. Lippmann, professor of physics at the University of Paris, is this:

> The problem, the research is the very essence of all science. Every science is the art of making researches. Doubtless there exist didactic treatises, theoretical expositions in which the acquired results are arranged in a logical order. But these results, these laws, these theorems are, above all, instruments ready for use. They constitute an intellectual chest of tools which is useless excepting to him who knows how to use it. The student who repeats the demonstration of a law or of a theorem without being able to make correct application of it, does not know what he is talking about; his science is wholly verbal. Without doubt he comprehends here and there a part of that which he commits to memory, but yet he owes to his memory more than he himself believes: frequently he fools himself, and frequently he even fools a professor at examination time.

The next address in the series was delivered by Mr Lucien Poincaré, Inspector General of Education in France. This is a particularly interesting contribution to the discussion before us It begins:

> With a unanimity, which is doubtless as rare in pedagogy as in other matters, we agree today in recognizing that scientific study ought to play in secondary education a role of far greater importance than educators in the past would have been willing to entrust to it.

He then points out that, if science is to play the important new part successfully, greater attention must be paid to the method of presenting the subject to the youth. We must know definitely the point at which we are aiming, and consider well the best use of the means at our disposal for attaining our educational purpose. From this point of view, the first thing that we must realize is that we are not attempting to prepare specialists in science. The factors that have been missing in the past education are the very ones that a properly directed teaching of science should develop; namely, a sense of concrete realities, a mind intelligent concerning positive truth, a mental and corporeal eye accustomed to see things exactly as they are.

Present conditions in the French schools are then shown to be anything but ideal in the matter of the presentation of science. The choice of subject-matter has been guided by superannuated traditions without respect for either interest or practical importance.

Teaching has followed but timidly the progress of ideas, and still clings to the methods handed down from generation to generation. To mention but one example, how many teachers, when they come to the subject of electricity, although they have at hand those simple and powerful machines which are of such great practical value and which also illustrate very beautifully and very clearly the immediate application of laws, still feel constrained to begin their course with a long and complete description of phenomena which, though known since antiquity, have yet remained very obscure? And they are satisfied with drawing a tiny spark from a piece of glass that has been rubbed with the skin of an unfortunate cat or with producing some feeble contractions on the legs of a frog, the innocent and obscure victim of science.

The students also, we are told, carry away the impression that the phenomena observed are inseparably connected with special pieces of apparatus, and thus that they do not penetrate into real life; and hence they conclude that physics is the art of setting into operation bizarre apparatus which is ordinarily kept in a glass case. The teacher seems to think it necessary to add a detailed description of some particular piece of apparatus to every fact mentioned and to every law stated; until, little by little, the apparatus takes on enormous proportions in the mind of the student, and finally usurps the place of the law; so that we find educated men who preserve, as their only recollection of the principle of Archimedes, a mental image of two copper cylinders.

Men who have been thus taught carry away from their study nothing but a load of scientific words without any ideas; they have listened passively, but have never become interested in the science that was taught them. Yet no sane mind could refrain from being captivated by a science that revealed to them a world so vast that it takes light, traveling at the rate of 186,000 miles a second, centuries to traverse it; yet made up of particles so small that they must be piled up by the million in order to make an object that would be perceptible in the most powerful microscope. The subject has been so crowded with details that have no particular interest, excepting to specialists, that the students once more fail to see the forest because of the trees.

After pointing out the evils that arise from attempts at rigor, and from the introduction of complicated, peculiai and exceptional experiments, which appear to the students as a sort of *complement de luxe* to the discussion, and which take away from science its educative value of developing an inductive habit of mind, Mr Poincaré continues:

> To set up laws a priori, as if they came from some unknown and mysterious revelation, and then to draw from those laws deductively their consequences, is to invert the real nature of things. This is the surest possible way of making scientific study serve to produce intellectual deformation, by inspiring some minds with a vague mysticism, and by paralyzing the deductive sense in other minds, thus sterilizing for all the imagination, by never bringing into evidence the creative function of an hypothesis.

Finally, he thus expresses himself with regard to standardizing the course in physics:

> I believe that it is desirable that our syllabi in physics should never become rigid. In the physical sciences there is no one and only logical order as there is in mathematics: we have to deal with too many complex ideas which are almost independent of each other to permit of establishing such a system that would not appear to be of an almost arbitrary character. For this reason, there is plenty of room for individual initiative in following out the particular needs of the students, so that the teachers can with advantage vary the order that they adopt in presenting their subject.

The next address in the series is by Mr P. Langevin, associate professor of physics in the College de France, on the Spirit of Science Teaching. Would that there were time to discuss this paper also. Many of the finer points, not already mentioned, are here made clear. But the subject before us is so vast, that the teacher must again be referred to the original documents for a more detailed study. Any one of these capital addresses furnishes food for thought for many days. How can we be expected to summarize the argument in less than one hour? Enough has, it is hoped, been adduced to show clearly that the ideas for which the French scientists are claiming recognition among science teachers are the same as those that are being pushed to the front in Germany; namely, connection of the work with the daily life of the students, use of the inductive method, emphasis on thought processes rather than on memory work, development of the scientific imagination, and a large amount of freedom for the teacher.

One more point is of interest in regard to the reform in France. In a letter recently received from Mr Lucien Poincaré, author of the address on the Methods of Teaching Science, he says: "During the past few years great progress has been made in opening up the sciences in a practical and modern way. The greater part of the criticisms which I made in the conference in 1904 would not now be applicable." Let us hope that here in America we may have as good a report to make at the end of the coming two years. The problem here is more difficult, because we have no government control of education, as they have in France. While there but one governing body had to be converted in order to inaugurate the reforms, here we have a very large number that control the standards in education. On the other hand we Americans have a large fund of common sense which makes us quick to adopt and to enforce new ideas, and so the chances here should be as good as those in the countries across the water.

In America the organization of the movement for the reform of physics teaching has been going on for some time. For a number of years, the belief that the methods of teaching physics here did not lead to results commensurate with the time and money expended on it has been growing in strength and extending to all parts of the country. The signs of this growing dissatisfaction with the subject are manifest everywhere. For example, within the last six years numerous local associations have prepared special lists of experiments for use within their territory, lists that show a tendency to break away from the list adopted by the National Educational Association, on recommendation of its committee on college entrance requirements, in 1899. In 1904 this association itself appointed another committee to revise this list, and approved a new list presented by this committee in 1905. The report of this committee contains, in addition to the list of experiments for the first year in physics, an excellent outline for a second year of work.

All of this work on lists of experiments has led to a marked elevation of the grade of work done in the high school laboratories, but it did not concern itself much with the methods of presenting the subject in the classroom. That this side of the problem was also coming to the front, was shown by the fact that a number of new textbooks began making their appearance — texts in which the effort was made to lay emphasis on the thought processes, rather than on the mastery of the subject-matter.

Another and still more important sign of the awakening to the fact that there really was a serious problem here for consideration is the establishment in various parts of the country of associations, formed by the physics teachers themselves for the purpose of helping one another to improve the work. For the past 10 or 12 years these associations have exerted, and they still exert, a powerful influence for good over the teaching of the subject. By uniting the teachers for the solution of their common problems, they have been a source of inspiration to all of their members; and they have served, by the preparation and publication of excellent reports and by their fruitful discussion of vital topics, in advancing the efficiency of physics in a truly admirable way.

The organization for the betterment of physics teaching may then be said to have begun with the founding of the first of these associations, the Eastern Association of Physics Teachers, which was established on February 2, 1905. It is interesting to note that in this country this organized movement was begun in a truly democratic way by the teachers themselves; not, as abroad, by government action. The example set by the New England physics teachers has been followed by their colleagues elsewhere, until now we have a large number of these flourishing associations scattered all over the country.

The establishment of these associations seems to me to mark a new epoch in educational work. In the past, the methods to be used and the subject-matter to be taught in the secondary schools have been determined by the enactments either of bodies of school authorities, or of college faculties. In the framing of these enactments, the man who was to do the work — the man behind the gun, we might call him — had little if any voice. Even though many of the committees of the National Educational Association, for example, had some high school teachers among their members, these men could not represent the secondary school interests as completely before the establishment of the teachers associations as they now can after the problems have been defined more sharply by the discussions in these association meetings by large numbers of their colleagues. Hence the importance of these associations lies in the fact that they furnish to both high school and college teachers the much needed opportunity for a free and open discussion of their common problems. This gives to the high school teacher a kind of representation in the enactments of ruling bodies which he did not have before; and it tends to counteract, in a thoroughly healthy way, what Pres. G. Stanley Hall calls the authority that works from above downward.

This statement does not in the least reflect on either the sincerity or the efficiency of the school authorities, or of the committees of educational associations. The work that has been done is doubtless the very best that could be done under the conditions that existed at the time. Moreover, this work had to be done at first in this way; because, in the building up of our system of secondary education, trained teachers for the positions created did not at first exist. Hence those who did understand the educational problems best had to take the lead. But now the conditions have changed. Secondary school teaching has developed into a profession; and this profession is filled with hundreds of capable, earnest and thoughtful men and women, each of whom is a specialist in the profession, and understands his business now in a way that was rare some few years ago. If it were not for the work already done, and effectively done, for the schools by those unselfish labors of the few who devoted themselves to the task, we would not now be in a position to go on and expand and extend that work by using the skill and the experience that has been developed in the secondary school teachers because of that work.

But since there now exists this large and efficient body of well trained and experienced secondary school teachers, as well as the smaller but no less efficient body of college instructors, and since all these teachers have developed their associations for the united study of their common problems, it seems fair to ask, whether it is not now the time to make these associations take an active part in the work of standardizing and coordinating courses of study, and in defining the conditions under which good work is possible in each of the subjects, and in determining the methods of presentation that are best suited to each particular age of the student. Are we not now ready to try to define high school courses, college entrance requirements, and college courses by joint cooperative action of all the teachers through their associations? And do not these associations furnish the means of getting expressions of opinion on every problem from hundreds of active teachers, instead of from a committee of 5, or 10, or 12 members? And would not the result thus obtained be more far-reaching, because every teacher had been able to follow the discussion and to add to it, than results obtained by the star-chamber work of any committee, however efficient, diligent, able and sincere its members might be?

And, when we think of it, is it not right that this sort of an innovation should come from the science teachers? For what is this proposition, but one to apply the scientific method to the educational problems, and to attempt to observe and study every possible case, before drawing a conclusion? Besides, as has been abundantly shown in the foregoing discussion, science teaching needs renovating and rejuvenating — nay, needs remaking, more than the teaching of the other subjects, perhaps.

If it is agreed that such wholesale cooperation and mutual assistance among teachers in the colleges and in the secondary schools is desirable, it is fair to ask how it may be obtained through the associations. One method of doing this has developed in the past year among the teachers of physics. I say developed purposely; for the idea may be said to have been thrust upon those teachers by the force of circumstances, rather than invented by them. The story of this work is as follows:

A little over a year ago, several members of the Central Association of Science and Mathematics Teachers, feeling the currents of the times, and realizing that the teaching of physics might even yet be improved, asked that association to appoint a committee of three to investigate and see what had better be done. This committee began work by sending a circular letter to about 1500 physics teachers asking for an expression of opinion from each on a number of points. The questions were not very easy to answer, since they asked each teacher to give his justification for his carrying on his work as he did. The purpose in the mind of the committee in sending these circulars to so many teachers, was to give every one who could be reached a chance to express his views. This idea is not new.

Shortly after this circular letter had been sent out, the North Central Association of Colleges and Secondary Schools held its annual meeting in Chicago. This association makes it a special point in its work, to so arrange matters that all problems are solved by cooperative action between the colleges and the secondary schools. As an example of their method of work we may note the fact that they had voted at their previous meeting to appoint a separate committee for each subject to define the unit of work in that subject; and, the important point, each of these committees was to consist of 20 members, one high school man and one college man from each of the 10 states represented in the association. The state examiner of schools in each state was to nominate the members of these committees for his state, so that the members of each committee of 20 were nominated by 10 different men. In this way a thoroughly representative committee was obtained. This idea of democratizing the work, by working with large committees, is thus due to the North Central Association.

The physics committee that was thus appointed happened to include among its 20 members the three who had been appointed by the teachers association to do a very similar piece of work. The original committee of three, having, as it were, been thus unexpectedly increased to a committee of 20, and its duties having been expanded to include a redefinition of the unit in physics, thought that it might as well expand the work still more, by inviting other associations to appoint similar committees, so as to get the interest and the cooperation of all the physics teachers in the work, with the hope of making the new definition of the unit as cosmopolitan in character as was possible. This was done, with the result that 12 other associations have joined in the work by appointing committees to represent them. There are, therefore, 14 associations now cooperating on the problem; the cooperating committees number all told 52 members, and the associations represented count about 1200 physics teachers among their members. Should not an organization like this be far better able to solve the problems of the teaching of physics, than could the science section of the National Educational Association, for example, which counts less than 50 physics teachers among its members?

Whenever an association joined in the work, a list of its members was obtained, so that every physics teacher who belonged to any one of the cooperating associations might be reached and given a chance to express his opinion. Up to the present time, about 400 of these teachers have taken advantage of the opportunity thus given, and have contributed ideas and suggestions to the discussions that have been carried on by means of printed circulars. It is as yet too early to foretell what will be the final success of this undertaking, but a great deal has been accomplished in the way of arousing enthusiasm among the teachers for their work. Would that there were time to quote from the many letters that have been received, in which the effects of this work on the work of individual teachers are described; suffice it to say, that the agitation has already led to the establishment of two new science teachers associations, and two others are in the process of being organized this week because of it. Seven associations have made the discussion of this work an important, if not the main theme of their annual meetings held this fall. It seems safe to say that when the meaning and the scope of this work is rightly understood, results of importance may be obtained by it. Many teachers have not yet grasped its significance; but when they do, they will not hesitate to add their voice to that of the others, and so to give impetus to the work.

One great advantage of this kind of work is that it helps to build up the associations engaged in it. It stimulates the teacher to know that he is called upon to do some work for his association; it makes him feel that the association needs him, and so urges him to make an effort on its behalf. It also stimulates him to be brought into touch with the ideas of his colleagues, and thus necessarily makes him a broader and a better teacher. It has been proved clearly enough that this form of activity is a very essential part of the functions of every association, since it keeps the members in touch with one another throughout the year, and thus sustains the enthusiasm begotten at the annual meetings.

This method of getting the science teachers associations to coöperate in the solution of their problems may be summarized as follows: Each association appoints several members to represent it in a general large committee. This committee formulates a plan of action, and carries it out by means of printed circulars which are sent to the individual members of each of the associations. The formulation of the results and the decision concerning what action should be taken is made by the large general committee by correspondence. The small committee of each association reports to its association such portions of the actions of the general committee as it approves, and each association is then in a position to accept or reject these results as it may think best. It seems as if this method gives each individual teacher a representation in the results that he would not otherwise have.

In this discussion of the American conditions, we have thus far considered mainly the administrative side of the subject: *i. e.*, the part that the organizations have played and might play in this work, under the conditions of school administration peculiar to this country. That the educational principles that are guiding this agitation are very similar to those that are operative abroad, must be evident from the summaries of opinions printed in the circulars that have been issued, and from the statements in the first two pages of this paper. These principles call for: (1) The recognition of the fact that efficient teaching depends in the last analysis on the teacher, and not on curricula or on syllabi; so that every individual teacher must be given the opportunity of working at his specialty in as great freedom as is compatible with other interests of the school. (2) The recognition of the essential difference between instruction in science and that in other subjects, together with the consequent changes that become necessary in the method of presenting science. (3) The recognition of the fact that science, when properly presented, possesses as a subject of study a culture value that is at least as great as that of any other subject.

One word more, concerning the relation between this work for better science teaching and several other educational movements that have recently been started. A National Association for the Promotion of Industrial Education has just been formed. Since all of the modern industries are based on science — are, in fact, applied science — the new education in science has much to contribute to the work of this organization. Also a meeting was recently held in Boston to consider social and moral education, and an association may be formed for this purpose. Since a properly presented science has marked powers for developing the moral and ethical tastes of the students, the new education in science will have much to contribute to the work of this association. Let us hope that, when the time comes to try the science teachers in these new lines, they will not be found wanting. They certainly will be able to cope successfully with these new problems, if they develop their associations into a national organization for the cooperative study of the problems of education through science by the scientific method of investigation.

Lately I have been asked a number of times for a statement of the essential point, philosophical and pedagogical, of this whole agitation about science teaching. Such a statement would require pages, or rather volumes, for the complete expression of all that is contained in the problem before us. What seems to me to be an admirable summary of the whole situation, with its complex problems and its future destiny, has been given by Lord Tennyson in the verse:

Flower in the crannied wall,
I pluck you out of the crannies;—
Hold you here, root and all, in my hand,
Little flower — but if I could understand
What you are, root and all, and all in all,
I should know what God and man is.

For us science teachers the interpretation of this verse may be this: Shall we take this growing child, full of enthusiastic life, and, leading him to the little flower, teach him to say in his heart:

> I, the scientist, sharp sighted, clear minded, logical, keenly analytical, I will pluck you, little flower, and having murdered you and taken you out of your home and into my laboratory, I will chop you to bits and dissect you and examine you under my microscope; and when I shall have concluded the autopsy, I should know at examination time whether a professional botanist would classify you as a monocotyledon or as a dicotyledon.

Or shall we science teachers take this growing child, full of enthusiastic life, and, leading him to the little flower, teach him to say in his heart:

> I, the poet, the seer, the man who stands closest to Nature and feels most keenly the pulsations of her mighty heart, I will observe your life, little flower, and will watch you grow in the home where you have been planted; and I will try to discover what you can give to the great world about you, and what that world can give to you; and when I shall have done this, I should know what God and man is.

Section B — BIOLOGY

PLANT PHYSIOLOGY IN SECONDARY SCHOOLS

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A paper on this subject might properly deal both with what is and what should be taught. Adequately to treat the former topic would demand more time and labor in the collection of data than the speaker has been able to command. A word, however, may here be given to the present status of plant physiology in high schools.

1 What is

Here and there a school may be found in which the subject of plant physiology receives considerable attention, but in general it is not well taught. The pupil learns incidentally a good deal about the things which plants do but not much about how or why they do them. If a little laboratory work upon germination is done it is only enough to illustrate the fact that seeds sprout and develop into seedlings. The conditions necessary for germination, the wonderful change of the seedling from almost a saprophytic to a photosynthetic mode of nutrition are taken for granted or ignored. No studies are made of the interrelations of the endosperm (when present) and the embryo or of the mode of development and rate of growth of the latter. All the phenomena of irritability in plants are dismissed with little more than a mere mention, nutritive processes are hastily summarized and reproduction is regarded as of interest mainly as the function which has called into existence showy floral structures that may be "analyzed." All the way through, the pupil is required to do little more with the fundamental affairs of plant life than to read statements about them and retell these in his own language. Least of all is he required to vary the condition of the plant's existence until he has found out for himself the principal factors in some of its life processes and the upper and lower limits of temperature, light, moisture and so on under which it can exist.

In other words, the teaching of plant physiology is in many cases very meager and wholly textual and formal. To discuss the causes for this state of affairs would lead one no little way into the history of botany and of science teaching in general during the 19th century. It is to be feared that one reason why the dynamics of the plant world receive such scant attention is because it is more trouble to give instruction on that side of botany than on some others. Teachers have said to me: " I do not care to do much physiological experimenting; somehow it seems to me too hard to be sure whether the results are correct or not. Then it is discouraging for the class to have experiments fail." It is needless to ask how one would rate the chemistry or physics teacher who made such a remark. Plant chemistry and plant physics are doubtless in part more difficult subjects than either science in its relation to nonliving matter. There is, then, all the more reason for doing elementary laboratory work to illustrate the simpler manifestations of energy in the living plant body. It may be granted that a moderate proportion of one's physiological experiments will usually fail — what of it? The most instructive experiment which I ever performed was a failure. A plant of Ficus elastica had been under observation for a week or two in a set of measurements of transpiration. Finally it was watered to the point of filling the pot up to the lid which was cemented to its top. Instead of transpiring more abundantly the plant suddenly ceased to lose water through its leaves. Day after day it was reweighed with the same result, until a yellowing leaf at once gave the clue to the situation. It was dead, and dead plants do not transpire.

2 What ought to be

No one can lay down a course in plant physiology which the high schools should be expected to follow in detail. Botany in some schools is studied for 18 or 20 weeks and in others for a year and a half. Its place in the curriculum is anywhere from the first to the last year. These facts alone would make it difficult to prescribe the kind and amount of work that should be done. But there is an additional difficulty which arises from the fact that biological studies are so largely conditioned by the environment. The physiologico-ecological problems of the New England coast would many of them mean little to the St Louisian and still less to the Arizonian. As the political speaker has a different set of promises for every ward, so the judicious botany teacher will shape his courses somewhat with reference to the natural interests of his pupils. It is, however, possible to lay down some rules as to what it is best worth while to try to teach and how it may be taught.

There can be no doubt of the supreme importance of the physiological side of botany. After all, structures exist only for the sake of the functions which they can perform and we are doing the beginner in botany a radical injury if we let him for a moment forget this. It is easier to keep a prepared slide than a growing plant, easier to demonstrate starch grains than starch manufacture in the cell, but that does not excuse the teacher for dissipating too much histological work. To me at least it seems unlikely that we shall often make the mistake of giving high school beginners too full or too accurate an idea of the processes of plant life. Fortunately there are enough good laboratory manuals to tell the teacher what can be done in this way and how to do it. The office of a paper like the present one is mainly to discuss the relative value of the several departments of plant physiology for secondary school instruction and to set down in orderly fashion some of the principal categories under which the subject should be considered.

In a general way it is evident that we should lay most stress on the processes which are most important in the life of the plant. But some of these, such as mitosic division of the nucleus, are far too difficult to be followed in detail by ordinary high school pupils. It therefore becomes necessary to modify our statement and to say that one should teach those topics in plant physiology which are of great intrinsic importance and which are workable under secondary school conditions. Clearly, following this course will throw a good deal of emphasis on the activities of the entire plant body or its organs as wholes rather than on intracellular work. It will also lead us as far into physiological ecology as the principals and superintendents will let us go. The fact that public school classes can not be kept many hours away from the school building precludes a great deal of field work. Still a good many subjects can be dealt with by means of reports on field work done by designated members of the class, supplemented by laboratory studies made by the entire division.

Summing up the subjects in plant physiology which can profitably be handled by a good secondary school class in a well equipped laboratory, they may be grouped somewhat as follows:

1 Growth and differentiation of the plant body, from the seed to the mature plant with seed of its own. Studies of the external developmental changes undergone by the plant.

2 The vegetative work of the plant. Studies of the nutritive activities of plant tissues.

3 Reproduction. Studies particularly of sexual reproduction all the way from the simplest zygospore formation to the fertilization and development of the ovule in seed plants.

4 Responses of the plant to the demands of its environment. Studies of all such manifestations of irritability as help the plant to adjust itself to its conditions of life. Also the investigation of some such plant structures as seem to have been evolved as means of protection against hostile conditions. This may seem much more ecological than physiological study, but after all there is little except the floristic and the geographical side of ecology which is not essentially a part of physiology.

It would be a wearisome and time-consuming labor to enumerate all of the studies and experiments which might be undertaken in carrying out the course of plant physiology just outlined. But it may be worth while to suggest a few of the most important topics to be dealt with under each of the four heads above given.

Under the first come studies of germinating seeds, investigating the conditions under which germination is possible and ascertaining the optimum amount of such factors as air, moisture and temperature. The rate of growth of the organs of the young seedling may be measured and their relative extension in various species compared, with discussion of the differences observed. The development of leaf buds may be followed through one season and the history of branches traced backward through many seasons. The origin and extension of conducting and strengthening tissues in root, stem and leaf may be partially followed. Evolution of flower buds into flowers may at least be outlined.

Under the second head the amount that can be done must depend a good deal on whether or no the class has any knowledge of chemistry. If it has, the whole subject of nutrition may be taken up in an elementary way. This should include studies of the sources of the raw materials of the plant body, of the osmotic activity of cells, of the transference of liquids throughout the plant body, respiration, photosynthesis, and the storage and subsequent utilization of reserve materials.

The treatment of the third general subject, reproduction, need not be discussed in detail. It is perhaps sufficient to say that a considerable series of studies of its simpler forms will greatly clear up the student's comprehension of what the process really signifies. It is perfectly possible to deal with some of the steps in the evolution of reproductive processes even in courses where not much time is spent upon the study of spore plants. This can only be done by concentrating the attention upon the gametes, minimizing the treatment of other stages in the life histories.

Under the fourth head, responses to environment, for satisfactory work, as already suggested, much of it must be done in the field. This, however, would in any case need to be largely supplemented by laboratory studies, and some topics can be handled entirely from the laboratory side. A very few of the subjects that may be investigated are the struggle for existence among buds and branches, the influence of varying degrees of illumination on foliage, the hibernacula or the summer resting condition of perennial herbs. Much that is interesting may be learned about the structural and functional variation of xerophytes under widely differing conditions as regards water supply. Heliotropism of stems and leaves and the changes of leaves and flowers from the diurnal to the nocturnal condition and back may be examined in a quantitative way. For the pupils who can do out of door work, even with a single flower bed, a large amount of spring study can profitably be devoted to the actual working of floral arrangements for insect pollination.

But it is needless to multiply examples of the many points of view from which the plant may be approached and interrogated as to its life processes. One important suggestion is that every member of the class need not be — I had almost said must not be — given just the same observations to make and the same problems to solve. Much more can be done by allowing some liberty of election, at any rate in field work.

So far I have said next to nothing about plant physiology as exemplified by the lower forms. Of course the activities of the higher plants are so much more varied than those of the thallophytes that the former afford far more material for physiological observations. It would be difficult to put in figures the comparative responsiveness of a Pleurococcus cell and a sensitive plant, as they appear to the beginner in plant physiology. And yet the very simplicity of the life of the less differentiated spore plants makes them admirable material for the study of many life processes. Such subjects as osmosis and plasmolysis are nowhere better illustrated than by cells of Spirogyra. Ordinary cell division and multiplication by budding are well shown by Spirogyra and Saccharomyces respectively. Various movements such as ciliary action, phototaxis, amoeboid movements and protoplasmic streaming are best shown by certain spores or spore plants. The series of steps in sexual reproduction which culminates in the process as found in seed plants can be traced from its simplest form, as exemplified in Spirogyra and the desmids to its penultimate stage in Selaginella.

Among the higher spore plants there can be found many remarkable degrees of adaptation to extreme conditions as regards water supply. Most of the so called water ferns, for example, are true aquatics. The majority of our common ferns are denizens of moist woods. But some ferns, like various species of Notholaena, Cryptogamma, Polystichum, Cheilanthes and Pellaea are extreme xerophytes. A few of our ferns are tolerant of full sunlight, many prefer moderate shade and some, such as Cystopteris fragilis and Adiantum Capillus-Veneris, flourish in the mouths of caverns and rock shelters, where the average illumination is probably much less than 5 per cent of that of unshaded places.

Dismissing in this rather hasty way the outline of physiological processes to be studied and of material to be employed, there remains for discussion the manner in which the work is to be handled. Here the speaker must confess himself to be at a decided disadvantage. For in nearly 25 years of botany teaching it has been his misfortune always to have had to do without any laboratory facilities worthy of the name. There may be other such unfortunates in the audience, teachers who have also been victims of homemade apparatus and of the school desk masquerading as a laboratory table. Experiences of this sort lead one to emphasize as indispensable for satisfactory results the use of an adequate, well stocked laboratory. For physiological work most important requisites are well regulated temperature, sunshine and (if possible) a small greenhouse or its equivalent. Even a large, heated bay window with waterproof floor and an atmosphere kept thoroughly moist by large exposed surfaces of wet sand or other porous material will answer. It must be kept in mind that in winter the air of rooms heated and ventilated in the ordinary manner is practically desert air, capital for decided xerophytes but death to many of the plants best worth studying.

In the way of expensive apparatus the secondary school need not provide much except compound microscopes, a clinostat and some moderately sensitive balances. Fortunately the temperature relations of plants can be quantitatively studied with a chemical thermometer, the light relations with a watch and bits of sensitized paper and the transpiration rate with a fairly good balance. These are only typical examples of the many cases in which actual research of scientific value can be accomplished in the field of plant physiology with very simple appliances. The golden mean in regard to apparatus is to give the pupil enough to secure good results but not enough to spare him taking pains or to obscure his view of the process under investigation behind too complex appliances for observing it. Probably most high school pupils would not observe as carefully or as long remember their results concerning the growth of internodes, measured by a self-recording auxanometer as they would such values as could be secured by the use of a pair of dividers and a millimeter scale.

It is still to some extent a mooted question whether the pupil should be told beforehand what values he ought in any given experiment to obtain. Some teachers (otherwise sane) insist that it is necessary first to teach the correct results in order that the pupil may not obtain for himself incorrect ones and then remember them forever. To me this fear has always seemed baseless and many experiences have led me to apprehend much more danger from setting the student to work under the influence of preconceived ideas. Many years ago I had charge of the physics instruction in an important fitting school. The textbook in use contained a calculation of the specific heat of lead in which a wrong value was given for this constant. When the class reported their determinations of this specific heat, a large number of the results closely approached the wrong value given in the textbook. Now this sort of thing does not necessarily imply a deliberate falsifying of notes. It often means nothing more than that the student has reread his record and honestly felt that there must have been some mistake in setting down data. The next step is to revise these so as to eliminate the probable error. Any of us who have had enough laboratory training to have acquired the habit of accepting facts on experimental evidence, without the evidence of some other person to identify them for us as facts, find it hard to realize the state of mind of the pupil. His education may have been largely linguistic and (as has often been said) he knows of no way to find out the truth except to look through first the rules and then the exceptions of his grammar or its equivalent. Now though the experience of most of us would doubtless lead us to set laboratory work first and textbook statements, with discussion of results afterward, this plan does not preclude assistance from the teacher as the laboratory observations are in progress. It is an indefensible waste of time and of interest in the subject to let a student spend his laboratory period in futile attempts to get things going. If he is using the compound microscope for the first time and sketching mainly air bubbles, if he is trying to plasmolyze a dead Spirogyra cell, he should be set right at once. The frequent presence of the teacher at the pupil's elbow, in the laboratory, saves much waste of energy, minimizes the opportunities for copying the results of others, and secures thoroughness. The last point is most essential, for there are few temptations which more frequently beset the beginner in any kind of laboratory study than the tendency to be too easily satisfied with first results. In discussing with pupils the results of observations and experiments on yeast cultures made at home, I have found that immersing a test tube full of the fermenting mixture in boiling water for 15 minutes was usually reported to have caused increased production of gas. This result was given by the pupils in spite of the written direction to allow the mixture after heating to remain for an hour or more in a warm place. Of course the tube was examined while it was in the boiling water or upon withdrawal from it and not looked at afterward.

A most important practical question that at once confronts the young teacher who is arranging the schedule for his year's work in botany is how to divide the time between laboratory and classroom. Doubtless the former should have a good deal more than half of the time, but just how much more is a question to be solved for each case independently. To me it seems that the young and enthusiastic teacher is rather likely to overdo the laboratory side of the instruction. A good deal of experience in summer school teaching has convinced me that there are few cases of congestion more fatal than those of people who have accumulated a large mass of notes on experiments which they have performed in more or less complete ignorance of what they were doing and why they were doing it. They are left in much the same unhappy condition as that of Mr Alcott when at the close of one of his famous conversations on Emerson and the Concord transcendentalists he was asked by an alert Chicago board of trade man, "But Mr Alcott, what is it all for?" Perhaps as good a rule as any is to discuss laboratory results in the classroom as long as they naturally lend themselves to furnish material for interesting recitation. Then new queries may be raised and the class be put in an expectant attitude so that the opportunity to solve the new problems in the laboratory will be cordially welcomed.

In conclusion it may be well to say a word as to the amount of detail and the thoroughness with which the subject of plant physiology can be studied by high school classes. Authors differ most radically in the thoroughness with which they handle the fundamental topics of this subject. In some high school textbooks it is relegated to what is virtually an appendix, while in a few it constitutes the leading part of the general treatment of botany. Taking specific examples, one moderately well known book gives no more detailed explanation of the chemistry of photosynthesis than this: "Carbon dioxid taken from the atmosphere is somehow used up in this operation [manufacturing plant food], and the oxygen which is not needed by the plant is given back to be consumed by animals." Another book, rather difficult for high school use, gives about two and one half pages to the explanation, makes free use of the terms chloroplast and photosynthesis, gives the chemical composition of carbon dioxid and of water and states that photosynthetic work is due to solar energy. A still more striking disparity of treatment can be found in the case of the subject of fertilization in angiosperms. One author gives the topic (not including cross fertilization) 11 lines without a single cut, while another gives it nine pages with 12 elaborate cuts. The latter author also employs the most modern terminology, calling the pollen grain a microspore, the two cells within it resulting from nuclear division a male gametophyte the embryo sac a megaspore, and the egg apparatus with accessory nuclei a female gametophyte. Between such extremes of treatment as those just given there is a wide range of choice for the teacher.

The rigorousness with which the subject of plant physiology should be handled in the high school ought to be just that which will bring in the largest returns of knowledge of the subject and training of the student's powers without overworking him. Any approach to what ordinarily passes for the nature study method of presentation is out of the question. Too often such treatment in the lower grades has left the pupil saturated with the idea that he has "had" botany, physiology, zoology or what not and therefore quite unwilling to bend his energies toward learning more of it. On the other hand it would be most unfortunate if the subject were attacked in such fashion as to call for more reasoning power than the high school boy or girl has developed and thus become thoroughly repellent by reason of its real difficulty. Apparently the very exacting preparation in physics demanded by some college entrance requirements has, with great numbers of students, resulted in leaving memories of the course as one long nightmare. Our plant physiology should be sufficiently exacting to call for thoroughly careful laboratory work and subsequent reading; it should stand for much in the way of developing a scientific habit of mind, but it need not — must not — serve to make the plant world odious. Rather should it add greatly to the student's interest and pleasure in the society of his plant neighbors. If we can arouse in our students ever so little of that enthusiasm about the life and behavior of plants which animated such diverse investigators as Sprengel, Delpino and Müller, Humboldt, Grisebach and Schimper, Knight, Darwin, and Sachs we may feel that our teaching has not been in vain.

THE ESTABLISHED PRINCIPLES OF NATURE STUDY

(Abstract)

BY MAURICE A. BIGELOW, TEACHERS COLLEGE, COLUMBIA UNIVERSITY

On some most important principles — in fact the very foundations of nature study — there is agreement on the part of those educators and men of science who are now giving close attention to the progress of the nature study movement.

1 First, we have reached agreement in answer to the question, "What is nature study?"

Nature study is primarily the simple observational study of common natural objects and processes for the sake of personal acquaintance with the things which appeal to human interest directly.

Professor Hodge has defined nature study as: "Learning the things in nature that are best worth knowing, to the end of doing those things which make life most worth living."

Professor Bailey's conception as expressed in his writings is that nature study is the direct observational study of common things in the child's environment for the purpose of training the eye and the mind to see and to comprehend and thus to gain a sympathetic attitude toward nature for the purpose of increasing the joy of living.

Analyzing and comparing the three definitions above, there is harmony on every essential point.

The following points are essentials in the best current theory and practice of nature study: (1) direct observational study, (2) common things of nature, (3) from the standpoint of our human interests in nature as it touches our daily life directly.

2 The second established principle is that nature study should be differentiated from science. The strong tendency of recent years is to reserve the word science for strictly organized knowledge.

Nature study is primarily the simple observational study of common natural objects and processes for the sake of personal acquaintance with the things which appeal to human interest directly and independently of relations to organized science. Natural science study is the close analytical and synthetical study of natural objects and processes primarily for the sake of obtaining knowledge of the general principles which constitute the foundations of modern science. Along this line nature study for the elementary schools is being rapidly differentiated from the true science of high schools and colleges.

3 In essentials the great aims are as follows: (1) To give general acquaintance with and interest in common objects and processes in nature. (2) To give the first training in accurate observing as means of gaining knowledge direct from nature, and also in the simplest comparing, classifying and judging values of facts; in other words, to give the first training in the simplest processes of the scientific method. (3) To give pupils useful knowledge concerning natural objects and processes as they directly affect human life and interests.

4 The fourth established principle of nature study: There is quite general agreement that there is one fundamental method of teaching nature study, and that consists in getting the pupil to see and think for himself. Upon this depend the two of the three aims above stated — the aim for sympathetic acquaintance and the aim for training in thoughtful observing. Books may supplement good nature study.

5 The fifth principle refers to selection of materials for study. On this I see general agreement for the proposition that we should first of all select the most common and the most interesting from the viewpoint of everyday life. Hence outlines for various states will vary with the geographical distribution of the natural things available for study. But following the above principles, the general educational result will be independent of the particular materials studied.

6 The principles of child study must be recognized by teachers of nature study. This will force the proper differentiation from science of the higher schools.

These are the established guideposts which definitely mark the pathway of educational nature study. Progress or retrogression in the future will depend upon our application in practice of these established principles in theory. We have now reached agreement upon the working theory of nature study, the way is clearly defined, and the time has come for concerted action in practice. It is a serious question whether nature study is ever to be firmly established and universally recognized as an integral part of every elementary school course of study. The answer will be found in our future application of the principles now agreed upon. And in turn the success in practice will depend altogether upon the training of the teachers. It is a very significant and hopeful fact that wherever nature study guided by the established principles is presented by well trained teachers it is now recognized as an all essential part of a rational and liberal elementary education.

THE TEACHING OF BIOLOGICAL SCIENCES IN SOME OF THE HIGH SCHOOLS IN NEW YORK STATE

BY LESTER B. GARY, CENTRAL HIGH SCHOOL, BUFFALO

It was desired to know what uniformity there is in the teaching of the biological sciences in the high schools of New York State. A list of questions was sent to about 50 schools including those of New York city and Syracuse, as I was ignorant of the fact that representatives from these places had consented to speak of their work at this meeting. So my paper will deal largely with the conditions of the work in 19 high schools outside of New York city and Syracuse.

More or less complete replies were received from 30 teachers, and I wish to express my hearty appreciation of the kindness of those who answered my questions with considerable trouble to themselves.

Perhaps the chief interest in this paper lies in the question as to how many schools outside of New York city are giving a first year course in general biology.

Of those reporting, we find that seven are giving the course, while two of these give additional half year courses in botany and zoology or physiology. Eleven other schools give separate half year courses in botany, zoology and physiology, while one gives botany and physiology but no zoology. Rochester leads in giving an entire year's course in zoology and one in botany.

So far as I can learn, only two schools not giving a course in general biology, teach zoology and botany the first year. All of the others give these studies as either required or elective in the second, third or fourth year.

The question of age naturally depends largely on the courses given. In the schools offering only general biology in the first year, the pupils are the youngest. Four schools report pupils as young as 12 years though by far the majority are about 14.

Those schools in which the subjects are given later in the course have pupils ranging from 16 to 19.

One of the simpler questions was the length of recitation and the time given to laboratory work. The length of the recitation period seems to be generally from 40 to 45 minutes, though one school reports a 50 minute period, another, 35 minutes and still another gives only 30 minutes for physiology.

Seven schools have double laboratory periods and 12 schools have single periods, although three of these are in favor of the double period and intend to arrange for them if possible. Poughkeepsie reports a 10 minute recitation each day, followed by 35 minutes laboratory work until the topic is completed; then an entire period is given to oral recitation and another to written review.

Laboratory work in botany and zoology has a recognized place, so in many schools the new feature of general biology is the physiology laboratory. Six schools that do not offer the course in general biology, have laboratory work in physiology. One other because of lack of accommodation in its temporary quarters gives an equivalent. Five report no laboratory work and several are silent on the subject. Niagara Falls, although giving general biology, is not able to give laboratory work on account of the great number who are obliged to take the subject. Poughkeepsie reports a good laboratory course in bacteria, the blood, digestion and bandaging. Elmira is enthusiastically in favor of this work and says that students recite better, stand better in examinations, enjoy the work better and learn to think more clearly by it.

No questions were asked in regard to notebooks but a recent circular from the Regents seems to increase the burden of the teacher in grading them if its suggestions are followed. With all the work a teacher has to do in gathering material, preparing it and clearing away the debris, it seems too much to expect him to mark each laboratory exercise on five different points, and make an adding machine of himself computing grades.

One teacher has expressed the opinion that there is no surer way to kill enthusiasm in nature study than to mark every exercise on the basis of its English correctness. To the pupil it seems unfair that his deficiencies in English must keep down his grades in nature study in spite of faithful and efficient work.

The demand that notebooks be "absolutely perfect" in order to earn the full 20 points is a little extreme, for by a strict interpretation of this no one could receive the full 20. It is not possible that under this rule the better pupils may become discouraged, the poorer ones feel they have very little chance, and the work become degenerate? The grading of notebooks ought to be a relative matter in each class. A large number of the best, most able and conscientious members of the class ought to be able to obtain the grade 20 while medium and poorer pupils should of course receive less.

As a result of this agitation for marking notebooks on five different points, a teacher of long experience and great success has expressed the desire to do the laboratory work, make the notebooks but not submit them for credit in the examination.

One difficulty is that the faithful, conscientious teacher will mark every mistake and find, to his sorrow, that his notebooks have low marks while a more careless teacher will pass over many of these same mistakes, and his pupils, with the same, or even much poorer work will have better grades.

Therefore I wish to protest against too much machine work in our grading. An entirely practical aim is to compile notebooks that will be presentable and acceptable to college authorities.

I myself am working toward a system of outlines similar to those used in botany — a different one for each animal. These are typewritten and the students fill in the answers to the questions. Sometimes they copy the outline from the board and fill in the answers. It may be urged that this system is too mechanical, but it seems to secure some degree of accuracy and uniformity.

A surprising uniformity exists in the matter of excursions. Only two report none at all, while 16 schools are in favor of them. Both free and compulsory excursions seem to be the rule. The reasons for optional field work are because of expense, because of their occurrence on Saturday, or because pupils are employed after school hours. In the Albany school there is no compulsory field work, but the pupils are encouraged to make observations as they go to school.

Port Jervis aims to have pupils collect as much of their own botany material as possible. Nyack makes one excursion for plants and one for animals. Poughkeepsie has definite aims for field work as observation of autumn conditions of trees, collecting or pleasure. On the other hand one teacher, strange to say, has no excursions unless he is near a large museum. Perhaps the wisest one has field work every Saturday during pleasant weather, and then when the stormy days come turns them all to indoor laboratory work.

The answers concerning the phase of the subject most emphasized showed the greatest diversity of methods and marked individuality of treatment. They ranged all the way from the teacher who follows the syllabus literally, to the one who, with a broad view of the subject, seizes the great underlying principles and makes them live in the minds of his pupils.

One teacher of general biology emphasizes the physiological relations throughout the course; two others depend largely on experimental work in physiology, finding that pupils learn easily from simple experiments. One teacher is very enthusiastic over laboratory work in physiology while another condemns it with equal vigor.

In botany one teacher emphasizes gross structure of types forming an outline of plant life. Another pays greatest attention to the physiological aspects, especially of flowering plants, eliminating algae and fungi because few of her pupils will ever find their knowledge of them useful. A third eliminates all technical and what he considers uninteresting matter such as flower analysis and chemistry, paying most attention to drawings of roots, seedlings and so forth. While still another gives only sufficient anatomy for the classification of the plant. Lastly one teacher emphasizes plant fertilization as an introduction to animal reproduction.

In zoology different teachers put their greatest force into teaching physiological relations; biological aspects, such as mimicry and adaptation; anatomy leading to taxonomy; frogs and insects; living animals; haunts and habits. For myself, I consider it very necessary that the pupil see the specimen, and where an animal has a metamorphosis to show the complete life history. For instance, in the study of the frog, the pupils draw from actual specimens, four stages beside the egg.

The general aims of teachers are as varied as their methods. Gloversville aims to study the subject from the nature study point of view rather than the developmental side, and in order to develop their powers of seeing things, dwarfed by too much learning from books, has many observation lessons in class. On the other hand, while placing most emphasis on specimen work, another teacher thinks some study of the book should precede study of the specimen. Utica teaches patience by requiring pupils to focus their own microscopes, and mounts bad as well as good work on the boards for display, finding the pupils will discover their own mistakes from comparison.

Jamaica believes in training the powers of observation, and in leading pupils to make thoughtful deductions. Poughkeepsie teaches adaptation of structure to function, and environment and aims at a cultural value in the growth of mind and heart as a result from an understanding sympathy with nature; and believes that a discovery made for one's self, leads to self-reliance and to thoughtfulness for the rights of others. Lafayette High School strives for accurate and complete work and the teacher aims to make the subject as rich as possible in content. Rochester stands for investigation.

The statistics I have given show that a little over one third of the reporting schools outside of New York city give general biology. For this condition of affairs, principals, superintendents and boards of education are largely responsible. They will probably shift the responsibility on the general public and the taxpayer for failing to supply sufficient laboratory space, employing enough new teachers so that each one who teaches the subject may have time enough to do successful laboratory work. An example in point is a teacher who has taught botany, zoology and physiology for over 10 years without having as much as a faucet or sink in her room.

Right here I wish to express my appreciation of the subject-matter of the biology courses in the syllabus, in giving a wide range of choice of subjects, eliminating a great deal of dissection, and the substitution of more interesting work, making it a great improvement over the preceeding syllabus.

Doubtless many teachers would be glad to give the course in general biology because they could then employ all their time with biology and not be obliged to teach other subjects, if they had the consent of their school authorities.

On the other hand some teachers object to the course because the pupils are too young, and this is my objection. Another thinks it needs too great a knowledge of chemistry, and too much material, meaning, I suppose, too many topics. A Brooklyn teacher says there is too limited time for fundamental features of fundamental branches.

I can conceive that it would be difficult to keep the physiological unity of the course in mind, and the presentation of the subjects appears incomplete and unsatisfactory to a teacher who has been giving a half year to each branch. One teacher writes most earnestly of the need of one textbook covering the whole course and uniting it. Were it not for the difficulties of teaching young pupils the use of the microscope, I should like to teach general biology by beginning with unicellular plants and animals, following the logical order, and using plants and animals alternately, or as best suited to the topic in hand and ending with human physiology.

But for one, I very much object to giving up my older pupils in the junior and senior years in zoology. I have had a few of the younger sort and they do not know how to see or how to draw, and don't do good work in general. Their interest may be keener, but their visible results are poorer.

The principal objection I have to general biology in the first year is that it has been substituted by the Regents for half a year of botany and zoology usually given in the junior and senior year, for pupils preparing for training school. Such advanced pupils have learned to draw well and have so matured that they can do good work and appreciate the principles involved. In schools where conditions do not allow general biology to be given, a pupil fitting for training school, can, by a ruling of the Regents, substitute botany and physiology for general biology, thus entirely doing away with zoology as a requirement for training school candidates, unless the teacher can manage to work in a few scraps of zoology in the physiology course.

But many bright pupils pass physiology in the annexes or upper grades before they enter the high school proper and have largely forgotten it before the senior year. Thus we will have no opportunity to teach these pupils zoology or physiology with the laboratory appliances of our high schools.

When it becomes generally known, as it will be soon, that zoology is not absolutely required for entrance to training school, very few girls will take it, for many of them have a natural and acquired aversion to the study of animals.

In view of the great stress laid upon nature study nowadays, pupils intending to enter training school ought to be required to study zoology as well as botany, for those who do not will be at a great disadvantage. As Mrs Comstock told the association, "The one great obstacle to the introduction of nature study in the schools has been that the teachers were not prepared to teach it and were afraid to undertake it."

So I think that we, as an association, should most respectfully ask the Regents to reconsider this ruling allowing any substitute for zoology in the requirements for entrance to training schools. Therefore:

Resolved, That because of the importance of nature study, pupils for training schools should be allowed to make no substitutions in entrance credits, for botany and zoology, when they can not offer general biology.

BIOLOGICAL SCIENCES IN SYRACUSE HIGH SCHOOL

BY GEORGE T. HARGITT, SYRACUSE HIGH SCHOOL

The following biological sciences are taught: a year course in advanced zoology, a year course in advanced botany, both of these optional, and a half year course in human physiology which is required.

The zoology and botany come not earlier in the school curriculum than the second year, and very often the majority are from the third or fourth year. The age of the students varies from 15 to 18 years. The time spent is seven or eight periods each week, the periods being 40 minutes in length. In zoology there are three recitations and four or five laboratory periods, and in botany four recitations and three or four laboratory periods. At least two of the laboratory exercises, in both zoology and botany, are consecutive or double. If possible all are so arranged.

Zoology. The various phases of the subject are considered. In the laboratory morphology, of course, takes the main place, though this is made comparative; and physiology, development, adaptations of structure, classification etc. receive as much attention as possible. In the recitation some time is taken for an oral quiz upon the work done in the laboratory. Then questions of life history, function, ecology, evolution, economic relations, classification etc. are discussed. The class exercises are planned to be discussions instead of mere recitations. Often lectures are given by the instructor, both with and without the accompaniment of lantern slides. Standard reference books and several textbooks are referred to constantly by the students, and at times special topics — especially upon economic points, evolution, and development — are assigned to students for study, report to class, and discussion. Field work so far has been optional, sometimes in classes and sometimes individually with questions suggested and the course of study directed by the teacher. Reports of field work are always required.

Botany. In botany the work of the first term is chiefly physiological. Experiments are performed, sometimes individually and sometimes by the teacher in the form of demonstrations. These cover the main life processes of plants. In the second half of the year morphology is emphasized, especially comparative morphology to illustrate evolution. Ecology is taken up with seasonable topics. Systematic botany is touched upon in connection with the study of flowering plants, and economic topics come up incidentally. Considerable collateral reading is done by the students. As a rule this is voluntary though some is required and reports upon it expected. Lectures with slides are given several times a term. Field trips are taken both in the spring and in the fall. These are not required. Outlines are furnished beforehand, suggesting the important points to look for. Reports are required.

Physiology. A half year of human physiology is required of all students in the first half of the first year, that is, those just entered from the grammar school. The course followed is modified from the Regent's syllabus, and the students try our school examinations only. The time spent, at present, is three periods a week, two recitations and one laboratory exercise. Physiology is emphasized and anatomy subordinated. Hygiene is touched upon as a natural application of the experiments performed. The laboratory work is experimental, covering ground similar to that outlined in several of the laboratory manuals. Such experiments as tests of foods for the presence of the various foodstuffs, study of oxygen, the chemistry of respiration, are individual. More difficult ones, as osmosis, digestion, study of bacteria, are demonstrated by the teacher. Taken in this way the course is made more interesting and practical, and at the same time less superficial.

Biology. A series of circumstances has prevented the introduction of the first year biology course in our school. Among them may be mentioned first the very serious problem of the proper disposition and conduct of the large classes — about 300 — which enter twice a year, the school already being overcrowded. Again and more vital is a dissatisfaction with the course itself. While called biology it is outlined as three courses, viz: elementary botany, elementary zoology, physiology and hygiene. Furthermore these courses are made distinct and separate. Of course there is no objection to the unification of these by the teacher, but without specially trained teachers, examinations made distinctly biological, and textbooks written from a strictly biological viewpoint, the course will be taught as outlined. Indeed so far as I have observed or heard, it is at present taught as three distinct courses. Even with trained teachers and other conditions favorable the unifying of three disjointed courses would be a matter of no little difficulty.

Another very serious objection to the outlined course or even to a true biological course in the first year of the high school, is the tendency to superficiality. The objection may be raised that the course need not necessarily be superficial, but this is answered by the fact that it is so taught. I have had reports of the work as taught in some of the schools. In some places it is admitted that the course is pursued merely as nature study. From other places the report has come that the course is well liked by the students, and furnishes an interesting "diversion" for them. The center of interest was stated to be in the test tube experiments with oxygen etc. Undoubtedly the burning of phosphorus or a watch spring in a jar of oxygen, or the change of color in Fehling's solution when boiled with grape sugar, would be a novelty to the students and of course well liked. But nothing was claimed by the teacher as to real scientific value or enthusiasm. Nor was mention made of a satisfactory understanding and application of the phenomena mentioned, or of any other part of the course.

Recently I had an example of the results of the course as now taught in some of the schools. A boy taking the biology course in another city, entered our school about the 12th week. He came to my advanced zoology class and asked to be registered. Since he had no notebook, I questioned him as to what he had done. I found that he had "finished," as he said, the study of the grasshopper, butterfly, spider, crayfish, earthworm, clam, starfish, sea anemone, and was nearly "through" the frog. Thus he had done in 12 weeks about what I expected to study with the advanced zoology class in 40 weeks. From further questions as to how the forms had been studied it was evident that he was satisfied that he had about completed the study of zoology and was ready for the study of botany. He had no conception of the real meaning or value of the study, and his knowledge of facts was very vague and superficial. At least one other like example has come to my attention this fall. In this case the notebook was presented and the work found to be simply nature study and very superficial. This boy was allowed to enter the zoology class, but will be compelled to drop out at the end of the term. He apparently has little knowledge of even the forms he has previously studied.

The main value and training which come from the thorough study of a carefully constructed science course, is entirely lost by such teaching.

Section C — EARTH SCIENCE

THE STUDY OF MINERALS AND ROCKS IN PHYSICAL GEOGRAPHY IN THE HIGH SCHOOL

BY C. H. RICHARDSON, SYRACUSE UNIVERSITY

The subject assigned for my brief address before Section C, New York Science Teachers Association, is largely one of neglect. It is a matter of deep personal interest to many of us, though not to all. It may have been wilfully neglected because the teacher saw neither the mental discipline nor the utilitarian value that lies hidden therein. It may have arisen in other instances either from want of time to devote to the subject or from the lack of laboratory facilities with which to carry on the work.

Some of you may feel that the subject has no place in a program of this character or in a high school curriculum, that the first part of the subject should be relegated to the domain of mineralogy to be taught by the extreme specialist in the junior or senior year in the various colleges and universities; that the second part of the subject might better be divided between the university professors of geology and petrography. Therefore some of you may say that it is not geography and that it has no place in a high school or academy curriculum.

It is my purpose to show you in a terse discussion that this subject is one of intrinsic value and one well worthy of a definitely allotted time out of the 40 weeks of the school year. The vast majority of our secondary school pupils never enter college or push their way forward to a professional career. They seem contented with the equipment of a high school training, yet many fall short even of that goal. Shall we withhold from such the mysteries of earth science or reveal to them some knowledge of the composition and structure of the earth on which we live and move and have our being?

Physical geography embraces something more than the circulation of the atmosphere; something more than rivers and lakes, seas and oceans, something more than mountains and ravines. Mountains imply something more than a fold in the crust of the earth. They are often measuring rods, marking the amount of erosion that has taken place in a given area. The harder and more durable portions remain while the softer, less resisting material has suffered corrasion and been carried away. These lines of yielding mark the great lines of continental commerce both upon the water and the land.

Physical geography of necessity embraces to some extent the commercial element. It must consider not only these great thoroughfares of commerce, the site of these marts of trade, the grain and corn upon which peoples subsist, but also what makes the purchase of these commodities possible.

The civilization and enlightenment of a nation is directly proportionate to its industrial development. The opening of the mine for the extraction of some metal claims a part of the forest for the requisite timber for the mills, and a part of the plain for the growth of grain that shall become the sustenance of the miners. The United States alone in 1905 gleaned $1,632,000,000 from her mineral industry.

The pupil can best interpret the phenomena by a careful study of a few minerals that have contributed so largely to this gigantic sum.

In addition to the commercial phase the lesson taught is one of cleanliness, individual discrimination and accuracy. In scarcely any other field will the pupil rely more upon his own judgment than in the systematic study of the physical and chemical properties of minerals.

The three classes of properties of minerals need not all be considered so as to make the pupil a mineralogist. In few cases only do the morphological properties become of vital importance to the secondary pupil, yet he soon learns that some substances regularly crystallize in cubes while others are composed of prisms and pyramids. He finds galenite, pyrite and halite common examples of the first, and quartz and apatite familiar examples of the second.

Most of the pupils will not have had chemistry at the time when physical geography would be introduced, therefore the chemical properties scarcely fall within the scope of the discussion. Yet the teacher will mete out the chemical problems involved in the measure of the chemistry the pupils have had.

The physical properties are all important. The student will have his own scale of hardness and his own tray of minerals with which to work. A clear and concise definition of the various physical properties should be given, then the pupil can apply them to the minerals under consideration. The color, streak, hardness, specific gravity, magnetism, cleavage, fracture, tenacity, luster and diaphaneity are all within the range of the pupil. He sees how easily one mineral may be separated from another. He comes also to know something of their geographical distribution and their great economic uses.

With a reasonable length of time given to the study of minerals the pupil may become thoroughly familiar with at least 20 ores of economic value. Possibly the following minerals, since they are the most important ores of the metals represented: galenite, native silver, cinnabar, native copper, chalcopyrite, malachite, native gold, hematite, limonite, magnetite, siderite, bauxite, sphalerite and zincite. The order of arrangement is not that of the importance of the minerals but of the group separation of the metals involved. From these 20 minerals nearly $700,000,000 of products were extracted in 1905.

If we take into consideration either the coining value of the silver or the pigments manufactured from the lead ores the amount is swelled beyond the $700,000,000.

A few nonmetallic economic and rock-forming minerals may be studied in a similar manner to a good advantage, as graphite, sulfur, gypsum, calcite, apatite, fluorite, halite and quartz. The more common of the feldspars, micas, pyroxenes and amphiboles should also be considered.

Scarcely a secondary school exists that does not have access to the various types of building materials, as granites, gneisses, syenites, sandstones, limestones, marbles and slates. As the pupil visits the quarry to study joints, faults and weathering it will add to his interest if he collects for himself the material he is to study in the laboratory. Thus the pupil will become familiar with many types of both sedimentary and igneous rocks and early learn their application to human industry.

The study of soils, which is a very important feature in physical geography, is enriched by some knowledge of minerals and rocks. These are the parent source. The kind of rock determines the nature of the soil and in fact the kind of crop best adapted to that soil. In the dry, pure sands arising from the breaking down of sandstone, a farmer does not plant his corn unless he expects a harvest of weeds. He knows how productive of grain and corn are the marls and thereby profits by his knowledge. The pupil soon learns that not only the various crops but also trees and flowers, are dependent both upon the climate and on the nature of the soil. One tenth at least of the 40 weeks of the school year should be given to the study of minerals and rocks.

The student should collect upon his field trips and prepare for his own study as many different samples of soil as are found in his community and know their composition and their origin. This is about the proportion given by some of our best high schools and recommended by the State Regents.

In this study of the minerals and rocks I would let it embrace as much of nature as the individual pupil is able to comprehend. Trace their influence upon the geography and topography of the earth's surface. Contrast the mountainous scenery of the granites with the tamer landscape of the limestones. Show how the migration of races and the progress of civilization has been largely dependent upon these factors. Trace their relation to roaring cataracts and majestic canyons, to thriving cities and countless manufactures. This will give greater breadth to his vision, scope to his imagination, zeal to his work, and your efforts will not prove amiss.

BARACHOIS, BAR AND TICKLE

BY JOHN M. CLARKE, STATE GEOLOGIST, ALBANY

It is my purpose briefly to discuss under this title the physiographic significance of what is commonly termed a coastal lagoon and I have in mind especially the recognition of such lagoon deposits in the succession of rock formations. It is not so much that I have to present a novel conception in geological interpretation but rather the wider application of an old one, whose validity is in danger of invasion by what seems to me overstrained conceptions of agents pertaining to a distinct category.

The coastal lagoon is a feature of many coast lines and is of general distribution. It is an area of semiimpounded water receiving terrestrial drainage, and at some time in its history, if not at present, receiving it abundantly; cut off from the open sea by a sand bar through which at one or more points is a passageway, the outlet channel of the fresh water, the inlet passage of the tides, and kept open by flow and scour. The phenomenon is entirely familiar; to any American observer it must be especially so, for in modified and complex form these lagoons stretch along the Atlantic coast from Massachusetts to Florida. They are present on many coasts. They are absent on many. Their existence is governed more by local than by general conditions. One would be disposed to think of them as naturally forming along a sinking coast line, as they are doing with extreme irregularity and modification of form on the New Jersey coast and north and south. But they are features as well of a rising coast and are shown in typical unit expression on the rising shores of Gaspé in eastern Quebec. Their presence means the reaction between incoming land drainage heavily weighted with sediment and the opposing tidal flow of much denser sea waters. The sand bar is the result, behind it lies an immobile body of mixed salt and fresh waters, brackish, involving wholly changed conditions for the existence of the organisms of sea or river.

It is not therefore, that we have intricate physiographic conditions, with physical causes difficult to find, to deal with in such phenomena, but the consideration of immediate interest is this: that such lagoons, apparently of slender moment on the present coast lines of the world, have left momentous records in the sediments of the past. This is wholly to be expected. These are purely coastal phenomena. The succession of sedimentary rocks with which we deal is largely coastal, epicontinental, littoral in its origin and though customarily read as uniformly marine deposits yet it is now entirely evident that the coastal lagoon has from almost the beginning of the continents played a very important rôle. It rests with geologists to determine these effects and express them properly in terms of their agents.

I have adopted in my title and in this discussion the terms applied to these physiographic features by the inhabitants of Gaspé. Barachois is the lagoon, a Canadian word probably of Breton or Norman source; *Barre-à-cheois*, suggests the Abbé Ferland, a bar against the attack of the waves. Tickle is the passage through the bar, the tidal passage. It is not restricted to the shores of Gaspé as any one familiar with the coasts of Cape Breton and Newfoundland knows, but there it is applied loosely, often to the hazardous passages through a reef of rocks.

In the great peninsula of Gaspé the road about the coast avoids the long detour about the great barachois by running down one arm of the bar to the tickle over which the traveler is ferried. By heavy weather or with a rapidly flowing tide the passage is ticklish indeed. I know no other origin for this word than this arising from the subjective sensations of the traveler and I am informed there is no other. I commend these terms to the notice of physiographers. The word lagoon has no exact meaning in current use. A lagoon is the body of water within the inner reefs of a coral atoll, it is the abandoned meander of a river in its flood plain, it is the basin of a hot spring; in the broader Spanish meaning, it may be even a bay with narrow opening. It is also primarily a coastal lake impounded by a bar of dunes. It is an *Étang* at the mouth of the Rhone, but not so in Gaspé where an *Étang* is a fresh lake with a long outlet running into the sea.

The barachois is a definite unit expression of these reactions between continental and ocean waters. On the Prussian Baltic its exact equivalent is a *Haff*. Perhaps in the close analysis of these various physiographic expressions of work done it may be possible to assign to each a proper and distinctive value according to the nature of the agencies involved, but upon this condition I would lay particular emphasis: a barachois, a haff, excludes all notion of torrential drainage. These are phases of coastal lakes in which torrential stages with high drainage gradients have been passed. Torrential flow from elevated land surfaces may condition the origin of a true lagoon on the coasts of a newly elevated continent, but if so, the barachois is the decadent phase of the lagoon assumed as the gradient of flow is lowered by base leveling. I have indicated that lagoon is a confusing term with its many meanings — valueless in physiography unless restricted to one, and that the expression exhibited by the City of Lagoons at the head of the Adriatic, wherewith the existence of torrential conditions is involved. If perchance the physiographic category has now exhausted for the inanimate stages of geographical change all the terms applicable to the birth, growth, culmination, decline and death of the organic individual, all the appellations by which we denominate our conscious human struggles, ambitions, hopes, fears, despairs, achievements and failures, there may be room for terms so useful as barachois and tickle, each designating a well differentiated physiographic condition and phenomenon, neither inspired with sensation, consciousness or moral responsibility.

In Gaspé the expression of the barachois is entirely uncomplicated. The interior of this great peninsula is still well elevated but its topography is ancient, and away from the sea its sky lines are very gentle, its drainage ways broad and old. The interior of Gaspé is covered by a series of Appalachian rock folds. It is here, you will recall, that the course of the Appalachian folds changes from its usual northeast-southwest trend, first to east-west, then northwest-southeast, where it takes on the curve of the upper horn of the letter S. These extremely ancient rock folds and their troughs are still today evident in the topography of the country and in spite of all the erosion of all the ages the trunk streams of the country flow with great respect to these original troughs and the bays of the Gulf of St Lawrence enter into their seaward extensions often for great distances. In one of them lies Gaspé bay for a length of 15 miles, in another Malbay and at the head of every bay and *endroit* lies a barachois and its accompaniments.

It is my desire to call your attention especially to the nature of the sediments laid down in these barachois. So old are some of the Canadian examples that the contributory streams may have diminished almost to extinction, but where the indrainage is still active and large they are building up broad mud flats among many distributaries before reaching the waters of the barachois itself. For most of the year the deposits in the barachois are fine calcareous muds and for the freshet periods, sand, the materials for much calcareous shale and some limestone. In their earlier history before the country was so nearly planed the conditions were favorable for the deposition of much sand and less mud, much sandstone and less calcareous shale. Sandstones and calcareous shale or even limestones are then the rock which are properly open to the inquiry as to whether they may indicate barachois conditions in a very ancient past. Let me observe that conglomerates and rubbles have no place in the category of lagoon deposits. They are the debris of an open sea pounding against a bold and rocky shore. The observation is worth making because such formations have been at times ascribed to ancient lagoons and deltas. In a delta emptying abruptly on an exposed coast they are possible, but otherwise not.

Not every mass of calcareous muds, however, and not every deposit of sands are of barachois origin, not every rock formation of shale and sandstone indicates such conditions in succession of geological deposits. What is the index? How is the one to be told from the other where there is no lithic difference in the deposits of the barachois and the open littoral? It is perhaps needless to say that it lies in the embedded fossils when properly interpreted, but before referring to this, there are guiding indications of another character. The oxidation of the iron in the barachois muds by the organic acids under the action of the sunlight gives to the resultant limestone rocks an often brilliant coloration in shades of red, which it seems entirely probable they could not have acquired at a depth or over a sea bottom too deep for the sun to reach. I will not go into detail in regard to this point. It has been the subject of careful investigation by German and Swedish chemists who conclude that such a brilliantly tinted limestone must have received its colors by oxidation of its iron in shallow waters within reach of the actinism of the sunlight. Limestones and lime shale then, may be, contrary to quite commonly received ideas, the deposits from the shallow waters of the barachois.

Let us take an illustration from that most illuminating country to a geologist, Gaspé. Off the coast of Gaspé stands an amazing and imposing monument to the destructive powers of the sea, the stupendous Percé rock, the most dramatic feature on the American coast, an isolated mass of brilliantly colored red and yellow Devonic limestones. Twenty miles to the north Devonic limestones of the same age and with the same fossils appear in great force and between these two exposures rolls the sea. The strata at the north are gray and somber, with their profusion of fossils scattered indifferently through the strata. In the brilliant limestones of Percé, however, the same fossils are present but are few and lie in distant layers with barren intervals. The tinted limestones came within the reach of shore drainage and the sunlight. The gray strata with which they are continuous were laid too deep for these effects.

The organic life of a barachois will be very different from that either of the contributing fresh waters or of the receiving ocean littoral. The waters will be brackish; the inhabitants such as can adapt themselves to brackish conditions. These will be few, they may be in their origin in part marine, in part continental or aquatic. Barachois deposits will then be largely barren of animal life compared with the true littoral. There will be times of stress when in every barachois the ocean's storms will wash over the bar or through the tickle the animals, dead or alive, of the littoral and spread out their remains over the bottom of the barachois. This would be the usual and normal, not the unusual condition. Barachois deposits may then be limestones or sandstones or calcareous shales and may contain marine fossils in separated layers with more or less barren intervals. These deposits will be likely also to contain fragments of land vegetation brought in by the terrestrial drainage.

It must be concluded that extreme caution is requisite for the exact recognition of barachois deposits in the geologic succession in their discrimination from true marine littoral formations. Close analysis of many conditions will alone suffice for such determination. Reliance upon one or another single characteristic may easily lead to misinterpretation. But as caution is requisite, if it is exercised, we may be confident of the result.

On the other hand there should be no confusion between such deposits and those of such torrential origin as imply arid conditions of climate. Let me speak briefly on this point. A treatise by a German investigator on desert characteristics and the conditions leading to desert formations, the instructive study by two British authors of the qualities of wind-blown and waterworn sands, all rich in suggestiveness, have been subjected to the somewhat American proclivity to extravagance and exaggeration and we are asked to interpret many of our relatively barren sandstone formations as deposits accruing under the torrential drainage of arid climate. Herein we find this weakness in the proposition; for though arid conditions may involve torrential drainage, torrential drainage does not imply arid conditions. Indeed the typical lagoons of the Adriatic today are results of torrential drainage and delta deposit but the climate conditions are certainly far from arid.

True lagoons with their early accompaniments of high inlet gradients are the natural recipients of deltas; in the barachois stage delta deposition may be less apparent. Under the first, heavy accumulations of sand will normally occur and such do not necessarily imply torrential drainage, nor at all involve arid conditions. Barachois with their flats drying out in the sun into mud-cracked surfaces, and assuming a brilliant coloration by oxidation are the very proof of absence of torrential drainage and no necessary associate of arid climate.

Did the time permit, I should wish to illustrate the geological importance of barachois deposits by referring to concrete examples in the New York series of geological formations. This I can do here but very briefly. It has been recognized that a certain aspect of the Devonic rocks expressed in the Old Red sandstone facies indicates fresh or brackish coastal lakes. It is to Hugh Miller we owe this conception. The distinguished Scotchman compared the conditions under which this Old Red sandstone was deposited to those existing today in Lake Stennis on the Orkney islands whose outer reaches, where in communication with the sea, are highly brackish but whose inner portion, cut off from the free access with the outer, are well nigh fresh. This conception has been elaborated by several students of these formations and we are reasonably secure today in interpreting the Old Red sandstone not alone of Great Britain and Russia, but its equivalents, the 7000 feet of Gaspé sandstone in Quebec and the 4000 feet of Catskill sandstone in New York as the continued deposition in coastal lagoons receiving rapid drainage and delta-filled, holding brackish water and open to the sea by passages or tickles which permitted the free circulation of the marine plankton represented by its fishes, having its bars overwashed at times in periods of stress without, as shown by an occasional layer of marine fossils. The Catskill formation in New York is not alone Devonic in age but without change or interruption transcends the Devonic boundary and its upper portions were laid down while marine Carbonic faunas were holding the seas in southwestern New York and elsewhere. This conception, first put forth by James Hall in 1875, has been elaborated and verified in these later years. Ten years ago, I undertook to indicate the existence of a still earlier coast lake in New York, to which the name Lake Oneonta was applied. It was the lagoon or barachois which preceded the Catskill lakes and opened the way for them. It was of the same nature, delta-filled by heavy erosion, its sediments full of drifted terrestrial vegetation and abounding in almost the earliest representative of our unios or fresh-water clams, the Archanodon or Amnigenia catskillensis. In these instances we have to deal with cases of rapid deposition, hence the heavy sand deposits of a lagoon as distinguished from the prevailing muds of a barachois. In Gaspé, which is geologically a part of New York as it affords a brilliant presentment of the New York formations, were tremendous lagoons represented by the heavy Gaspé sandstone which began in the lowest Devonic and continued to near its close and we have there also the singular and illuminating phenomenon presented by what Logan called the Bonaventure conglomerate, a mantle of alternating conglomerates and sands which seem to indicate a constant shifting of currents and coast, perhaps at no time clearly presenting a lagoon condition, but nevertheless transcending without break, as does the Catskill formation in New York, the boundary between the Devonic and Carbonic formations.

In the earlier Devonic of Gaspé we may have true barachois conditions as I have already intimated in referring to the brilliant limestones of Percé rock with its marine fossils.

Let me turn again to New York and cite a still earlier example of similar conditions, this time, however, involved not only in delta conditions but in those of a truly arid climate, and the only example of such conditions recognized in the New York formations. In this case I am sure you will be especially interested for it embodies a rearrangement of some ideas in regard to the correlation of the geological formations in our State. This is the case of the Shawangunk grit — the arenaceous deposit constituting the Shawangunk mountains of Ulster and Orange counties and continuing south into the Kittatinny mountains of New Jersey. You are all aware that every classification of these geological formations places the Oneida conglomerate at the base of the Upper Siluric series and below the Medina sandstone. A careful reexamination of the typical section of the Oneida conglomerate has shown that it is not below the Medina sandstone but in it. The Shawangunk grit of eastern New York has been uniformly regarded as equivalent in age with the Oneida. You will find this so stated in all standard textbooks and in all our own reports.

Now this Shawangunk formation is a conglomerate at its base and passes into a fine compact quartz sandstone or grit and becomes shaly toward the top covering a thickness upward of 700 feet. The same keen-eyed geologist who found the Oneida in the midst of the Medina finds that this supposed eastern equivalent of the Oneida lies directly and conformably under a shale (Longwood) and limestone (Cobleskill) which we know to be later in age than the Salina formation of central and western New York. Hence the natural and easy inference on stratigraphic grounds alone that the Shawangunk grit could not well represent the Oneida conglomerate but in a section where both Clinton and Niagara formations are absent it represented a probable equivalent of the Salina deposition.

For 70 years this formation in common with all others in this State has been hammered over but never a trace of a fossil seen until a few weeks ago, when another sharp-scented geologist of my staff ferreted out a fossil fauna that in its constitution and relations is of extraordinary and far-reaching interest. Such events let me say, are constantly transpiring in New York geology. It is the unexpected that happens and is likely to. Barrois, ex-president of the Geological Society of France, has said that the geology of New York is more completely known than that of any equal area in the globe. But still this great storehouse of geological facts continues to pour forth treasure in response to the endless tattoo of hammers and chisels, often to overwhelm us with her richness and to laugh at our theories.

Interbedded with these Shawangunk sandstones is an indefinite succession of thin black shales which carry an extensive fauna of those singular merostome or Limuluslike crustaceans, Eurypterus, Pterygotus and Hughmilleria like those lying at and within the base of the Salina of western New York (Pittsford shales) and in great number and diversity in the waterlimes (Bertie) at the top of that formation.

The Shawangunk grit therefore, after having been proved from purely stratigraphic argument as probably of the age of the Salina formation has now afforded the singular fauna peculiar to its initiatory stages.

We know that these creatures were of brackish water habit. We know that after their first appearance in the Salina, the impounded sea became too salt for their existence and that when the barriers were broken down and the sea freshened, they made their return in the decadent stages of Salina time. The culminant salt pan condition of the Salina with its heavy precipitation of salt implies beyond question an arid climate, but during this arid period while salt was precipitated in central New York there was not such precipitation at the east.

All the stratigraphic data now at our disposal point to the existence at this period of a bar extending southward from the coast in the present position of the Helderberg mountains. Time will not permit me to detail the evidence of this. Let us then assume it for the moment. The presence of this bar shut off from the confined and rapidly evaporating sea of central New York an embayment which evidently had an open tickle to the sea but which was receiving heavy delta deposits at the north: heavy, I mean in the sense that torrential action was involved. The frequent alternation of the Eurypterus shales with the delta sands of the Shawangunk grit shows that after slight deposition of the latter the crustaceans regained their ground in briny pools over the sandy shore.

Delta deposits then were laid down in a barachois or lagoon under arid conditions, and this lagoon constituted the earliest of which we have fairly conclusive evidence today.

THE RELATION WHICH SCHOOL GARDENS MAY BEAR TO INDUSTRIAL AND COMMERCIAL GEOGRAPHY

BY AMOS W. FARNHAM, OSWEGO STATE NORMAL SCHOOL

Many of our leading educators recognize school gardens as a valuable means of instruction in elementary schools. Many of our leading cities have made provision for school gardens; and many teachers have found that they contributed not alone to successful teaching, but to successful class management as well. Many children have found school work more congenial, and the schoolroom and school grounds more attractive because of their experience in, and the products of, the school gardens. The popularity of school gardens is shown by frequent contributions regarding them to educational magazines, contributed by enthusiastic advocates and read by teachers no less enthusiastic. Their popularity is often shown by programs of educational meetings in which school gardens receive at least "honorable mention." Occasionally a normal school indorses the school garden idea in a practical way, and in its annual report gives large, illustrated paragraphs on the subject. The United States Department of Agriculture, realizing that school gardens are an important and almost necessary means of instruction. has recently issued a pamphlet of 40 pages in which the value of school garden work is discussed. [This pamphlet is called *The School Garden*, and is known as Farmers' Bulletin no. 218.] In the President's message, under the heading, "Farming a Profession," the President says:

> In all education we should widen our aims. It is a good thing to produce a certain number of trained scholars and students, but the education superintended by the state must seek rather to produce 100 good citizens than merely one scholar, and it must be turned now and then from the class book to the study of the great book of nature itself. . . All students now realize that education must seek to train the executive powers of young people and to confer more real significance upon the phrase, "dignity of labor," and to prepare the pupils so that, in addition to each developing in the highest degree his individual capacity for work, they may together help create a right public opinion and show in many ways social and coöperative spirit.

It is now half a century since Europe instituted school gardens. Austria, Sweden and Germany were the first to introduce them, but other leading European nations quickly followed their example. These gardens were considered the most practical form of agricultural nature study. But it was not until the year 1891 that a school garden was opened in America, Boston taking the lead in the school garden movement. The beginning was a modest one, consisting of the utilization of a small plot of ground in connection with one of the grammar schools. This plot was devoted not to agricultural nature study as were the first European school gardens, but to the raising of native wild flowers. We learn that a few years later this same school added another small plot for the cultivation of vegetables — a step toward realizing the end for which the first school gardens were created and cultivated. In 1903, just 12 years after Boston had taken the initiative, statistics showed that more than 50 cities of our country had made some provision for school gardens. What has been done along this line during the last three years, we have not statistics at hand to show, but when we consider that the school garden movement is a popular one, and that Americans are not slow in putting popular ideas into tangible form, it is safe to say that the last three years have witnessed the opening of as many school gardens as had already been opened from 1891 to 1903.

School gardens in our country are almost entirely conducted in the interests of nature study, and are often denominatel nature study gardens. Now nature study does not seem to be very definitely outlined. In fact some of its strongest advocates say that it can not be outlined without doing violence to the spirit and aims of nature study. Some supervisors go so far as to leave their teachers free to choose the topics to be presented to the pupils under their care. This indefiniteness has brought out the criticism that nature study "has no beginning and no end"; that it begins with "almost any topic and ends whenever a sufficient number of topics have been suggested to fill in the allotted time." A school garden conducted in the interests of an unorganized course of nature study must share the same criticisms which such a course may receive.

School gardens are as yet in a stage of experiment. It is only 15 years since the first school garden was opened in America. Their function is not fully defined. Hence, the question arises, may they not realize all that is claimed for them, satisfying all of the demands of nature study, and at the same time be so well correlated with some of the phases of industrial and commercial geography that even a greater interest may be created in nature study, in school gardens and in industrial and commercial geography as well?

Some of the claims for school gardens set forth by the United States Department of Agriculture are, quick discrimination; skill with the hands developed by handling small seeds and various tools; systematic methods which follow from the order in which the operations conducted in the garden must be taken up; industry; the idea of ownership and the rights of ownership; business experience which is an important result of harvesting and accounting for the products which are grown; a basis of knowledge, provided the operations connected with the school garden are properly conducted, *i. e.*, if the requirements of the different crops in regard to preparation of soil, depth of planting, date of planting, and the time and manner of harvesting are all carefully observed. In connection with these already named, it is also claimed that opportunity is offered to illustrate the good and evil effects from certain methods of cultivation, of working soil when in good and bad condition, with the consequent effects upon growing crops; the value of deep and shallow tillage; methods of conserving moisture; importance of fertilization; and conditions essential to germination as well as conditions conducive to growth.

Now may not all of these claims be satisfied even in larger degree, if the attention is given to agricultural nature study (the study of cereals, grasses, fiber plants, saccharine plants, plants bearing oleiferous seeds, etc.), rather than to the cultivation of flowers and common vegetables? Again, would not a school garden in which are cultivated wheat, corn, clover, alfalfa, flax, hemp, sorghum, sugar beets, castor beans etc., help to realize the demands of nature study? We quote the "special purposes" of nature study from the Oshkosh State Normal School Bulletin of May 1906, designated *Nature Study Number.*

First,—to provide discipline, especially to the perceptive faculties, leading to the cultivation of close and accurate observation.

Second,—to develop the right moral spirit leading to sympathy, kind treatment, and right feeling toward life, especially animal life.

Third,—the work should aim to develop the spiritual nature, leading to reverence, trust, and belief.

Fourth,—to cultivate the esthetic sense, leading to an appreciation of nature's beauty,—including recognition of the beautiful, training in the securing of beautiful effects, and appreciation of the beauty of adaptation to use.

Fifth,—to arouse love of nature and desire for her acquaintance and companionship.

Sixth,—the work should help to maintain interest in all school work and aid in the work of other studies, especially language, reading, and drawing.

It is difficult to see why the cultivation and study of plants that administer to many of our physical needs may not "provide discipline for the perceptive faculties," "develop the spiritual nature," "cultivate the esthetic sense," "arouse love of nature," and "help to maintain interest in all school work and aid in the work of the other studies," at least in as great a degree as is realized from the cultivation and study of plants whose beauty is their only excuse for being. The cereals and grasses have long been subjects for the artist and the poet.

The advocates of nature study lay stress upon training the feelings. Surely this is good pedagogy, and is not to be lost sight of in teaching any subject in any nature study grade. A present day educator says, "The emotional spirit of instruction is the factor that counts."

And is it not true that the emotional spirit can be aroused and developed by considering nature from the economic side, the human side? Is it not also true that the child should be introduced to nature in its relation to his life, to his needs? We recognize the value of the aims and ends of nature study and of the nature study garden. And we believe that the selection of material may be in the interests of industrial and commercial geography, and at the same time contribute to the realization of the nature study aims and ends. We believe that nature study may be so correlated with industrial and commercial geography that each may aid in the interpretation of the other.

The first paragraph in the Oshkosh State Normal School Bulletin for May, the *Nature Study Number*, defines nature study in the following terms: "In general terms nature study is a study of one's natural environment. This study should be carried on in such a way as to bring about the most perfect adjustment of the individual to that environment, to the end of using it for the highest good. Nature study is learning those things in nature that are best worth knowing to the end of doing those things which make life most worth living." We could ask no better definition, but this definition is often lost sight of in nature study and in the selection of material for the nature study garden.

The school garden seems as necessary for the teaching of industrial and commercial geography as it does for the teaching of nature study, but the selection of materials for the nature study garden does not meet the demands of industrial and commercial geography. On the other hand, the selection of material in the interests of industrial and commercial geography would meet the demands of nature study. Let us see if it would not.

In considering the great human industries, agriculture and stock raising are first in importance. These two industries place man's food supply on a permanent basis. Now it is a matter of history that men can not rise out of savagery until they have placed their food supply on a permanent basis.

Our country holds the first place as an agricultural nation, and leads the world in the production of all varieties of live stock except sheep. Corn is our leading and most valuable crop, averaging over 2,000,000,000 bushels, and forming 75 per cent of the world's supply. And yet less than one tenth of this prodigious yield is usually exported in the form of corn. The greater part is fed to live stock, especially cattle and hogs. Hence a large part of the corn crop is exported in the form of meat.

The school garden should illustrate corn culture, pupils observing time of planting, care of the growing plants, and time of harvesting. They should note the time elapsing from day of planting to day of harvesting. They should note the character of soil best adapted for corn, and the effect of heat and moisture on the growing plants. The harvested ears should be used for schoolroom decoration. It will be recalled that some of our finest and most elaborate decorations at the Columbian Exposition and at the Pan American were made of different parts of the corn plant.

Again we lead the nations of the world in the production of wheat. The wheat crop in 1900 equaled 625,000,000 bushels. Wheat is the most widely distributed and the most nutritious of the cereals. More than one third of the world's population are consumers of wheat bread.

The school garden should give a space for the growth of spring wheat. The variety sown should be noted, dates of sowing and harvesting should be recorded, the period of growth determined, effects of heat and moisture observed, and insect pests, if any, studied. The ripened grain should be used in decoration. A small plat of winter wheat should be grown and many comparisons made with spring wheat.

Our country is exceeded in the production of oats by Russia only. Our annual crop some years reaches 1,000,000,000 bushels. Oats should be cultivated in the school garden; a careful study should be made of their growth, conditions for growth, and comparisons made with wheat and corn as to growth and conditions for growth. Pupils should discover how oats may be distinguished from wheat before the plants head.

Hay forms one of the most valuable crops in the United States. Its average annual value is $470,000,000, coming next in value to the corn crop. It is of great importance in the cattle-raising states of the corn districts, and also in the dairy states of which New York leads. "Hay" should include "timothy," clover and alfalfa.

The school garden should make the pupils familiar with each of these forage plants, from the seed to the harvested plants. Note that under favorable conditions more than one crop may be harvested in a single growing season. Pupils note which is the most rapid grower, and which are not true grasses.

The United States is the greatest sugar-consuming country in the world — every person in the country using, on the average, 70 pounds a year. Our greatest import is sugar. The sugar which we consume is very largely cane sugar. But our beet sugar industry is gradually increasing, especially in California, Nebraska, Utah and Michigan. Two thirds of the world's sugar product is beet sugar. Therefore sugar beets should be a product of the school garden, also one of the common varieties grown for table use. The growth of each should be studied, likenesses and differences noted, the matured roots compared, especially in saccharine qualities.

Sorghum being a sugar-producing plant, also a member of the same family of which sugar cane is a member, its cultivation would be of marked interest to the pupils.

Flax is one of the most important of textile fiber plants. It has a very wide range, thriving in the dry summers of California and in the moist regions of the Mississippi valley. It grows well in the colder parts of Europe and equally well in tropical Asia. Although almost every American citizen wears linen garments, only a small quantity of flax is grown in the United States, and that quantity is grown for the seed which is manufactured into linseed oil.

Because of the importance of the flax in contributing to our clothing material as well as to the arts, it should be produced in the school garden. Its beautiful blue flower gratifies the sense of beauty. A firm rich soil is the chief requisite for flax growth.

The true hemp of commerce (Cannabis sativa) is grown in nearly every country of North America, Europe and Asia. The prepared hemp is mainly used in the manufacture of wrapping twine, cordage and coarse canvas. The hemp is a stately plant, growing 3 feet or more in height, and commands attention when growing. Hemp seed forms a part of the food of caged seed eating birds.

Hemp should be found among the plants of the school garden. Hemp and flax fibers should be compared in color, length, coarseness and strength. Children should learn how each fiber is best adapted for its use.

The United States is the largest grower of tobacco. In some sections of our country, the cultivation of tobacco is the leading agricultural pursuit, and its preparation for use is the leading manufacture. It is a noble plant when growing, having a hight of 3 feet, and, when left to reach its greatest growth, attains a hight of 6 feet. Its leaves grow from 1 to 2 feet in length. Its flowers are 2 inches long and rose-purple. Tobacco in our latitude must be started in hotbeds; a few plants may get a start in the schoolroom. Its culture in the school garden may thus be practicable. Tobacco should be set in the school garden, back of plants of smaller size. The pupils will discover that liberal fertilizing is necessary for tobacco, and that it has its peculiar insect pests.

In some counties of New York, hop growing is a prominent industry. The hop is a graceful twiner, and may be trained over arches at intervals along the garden paths. Clusters of hops may be used in classroom decorations for the opening weeks of the fall term. Hops need comparatively little care, and yield good returns.

Other useful plants that may be cultivated in the school garden are broom corn; sweet potatoes, whose stems are beautiful vines; peanuts; chicory, producing bright blue flowers; rye; barley, and buckwheat. The herbs of the kitchen garden are of interest because of their flavoring qualities and wholesome odors. Among them are sage, spearmint, white mustard, caraway, summer savory, coriander, anise, thyme, dill, fennel, and sweet marjoram. Many of these enter into pharmaceutical preparations as well as into foods. Some of them have pleasing foliage and pretty, although rather inconspicuous, flowers. Their cultivation is simple and their care trifling. Their cultivation extends the child's knowledge of useful plants. A handful of sage or of summer savory from a pupil might be as pleasing in his home as a handful of scarlet salvia.

There are many useful plants from the tropics that may be grown in tubs. Some of these are coffee, tea, orange, lemon, banana, pineapple, rubber plant, date palm, and agave. Coffee as an import commodity in the United States is exceeded only by sugar. Coffee, sugar, and tea are used in every home. The citrus fruits, bananas, and pineapples are found on every fruitstand. All of the tropical plants are evergreen, and many of them are cultivated as house plants for their beautiful foliage. Plants of this order may be kept for geographical study, at the same time to add beauty to the school garden, and variety to the plant collection. A study of these tropical plants shows their peculiar needs, and how they may be adjusted to new climatic conditions. If the school can not keep these tropical plants safely through the winter, then a local florist will care for them in his greenhouse for a small consideration. Sometimes a florist will rent potted plants for the season. But school ownership means greater interest.

A school garden large enough to admit of trees should have at least one of each of our native conifers: white pine, spruce, balsam fir, hemlock, white cedar, and tamarack. It may also have a sugar maple, box elder (the ash leaf maple), and sassafras.

The matured products of the school garden should contribute annually to the school museum, and be used in geography teaching and nature study whenever they will illustrate such teaching.

The classes in drawing will find wheat, corn, flax, hops, chicory, the castor oil plant, clover and many other plants of the school garden both pleasing and profitable subjects for study. The artist prefers single flowers to double, and the more familiar plants to exotics.

Many school gardens are too small for the cultivation in one season of all the plants here named. In such a case, let there be rotation. " We have raised wheat, corn, flax, sugar beets, tobacco, and timothy this year; next year we shall raise rye, buckwheat, hemp, sorghum, hops, and alfalfa." This will hold interest through change of material, which in turn requires change of methods of cultivation.

The plan of the school garden must be determined by the kinds of plants to be cultivated; and the size of the plats must be determined both by the size of the garden and by the number of kinds of plants to be introduced.

Summary. The relating of school gardens to industrial and commercial geography would more nearly realize the aim which led to their being opened. Such relation would still furnish opportunity for the nature study work, and also correlate nature study and geography, thereby saving time and energy in teaching. Nature study and geography have in common much literature, art, manual exercises, and museum specimens. The two have field excursions, and use the brush, the crayon, and the molding board to express ideas. In one school Tiffany's nature study cabinet furnishes material for geography oftener than for nature study. The school garden as suggested in this paper would require far less outlay of time and money, and require less care than the nature study garden planted in flowers. Under the right teacher — and no school work "goes" unless under the right teacher — the emotions would be exercised on a high plane — the plane of patriotism. Many nature study advocates overlook the utilitarian idea. This idea is thought to be sordid. In this practical age, the utilitarian idea must not be lost sight of. The aim of education is or should be to develop the socially efficient individual. The first requisite of the socially efficient citizen is that he be able to "pull his own weight," that he be in no wise a drag upon society. A long step will be taken toward the development of the socially efficient citizen when the school garden is related to industrial and commercial geography.

REFERENCE BOOKS AND PHYSICAL GEOGRAPHY TEACHING

BY WILLIAM T. MORREY, MORRIS HIGH SCHOOL, NEW YORK CITY

Not a few of the high schools of the State of New York neglect the use of reference books in the teaching of physical geography. At the other extreme is Horace Mann High School where all books used are reference books. The increasing interest in laboratory work has tended to decrease the book work, perhaps, in a few schools; but, on the whole, the increased interest in the subject, the more excursions, the more lantern work tend to take the pupils into the library to supplement their texts.

Some teachers prefer to assign in advance to selected pupils specific topics to be reported on when the class as a class takes up the new subject. This method requires more thought of the pupil and benefits the individual most. Such reports may not be so good as those made by the pupils who approach their subjects with more preliminary knowledge. Many teachers prefer to present new topics in their own way. Another method is to have the reports expand, emphasize or make specific the subject that has been presented by the teacher and studied by all. The third method is the one I have used, not only to bridge the week or two between examinations and the end of the year, but also use it at times to prepare for the examinations. It serves as a pleasant and profitable review. It enables the pupil to apply his general knowledge to some specific new problem. It gives some training in work more or less of the nature of research. All the reports tend to acquaint the class with the available literature of the subject. There is also some satisfaction undoubtedly in being recognized as authority on at least one subject.

When I am ready to start this library work, I have every pupil make out a list of four or five topics in their order of preference, after I have read to them a list of topics that have been discussed or that may be worth discussing. Suggestions are asked. I then at my leisure go carefully over these lists and assign to each pupil as nearly as possible what he asked for or what I think will do him the most good. If necessary to cover very desirable ground, pupils are assigned topics without consulting their preferences.

Pupils report — sometimes by reading a formal report (counting at times as one of the formally prepared papers for the English Department), sometimes by an informal talk with or without brief notes. We have had very creditable pupil lectures illustrated by stereopticon.

Synopses or outlines on uniform paper have at times been required of every pupil. In later terms these synopses may be turned over to other pupils to combine, classify, criticize, or use in the treatment of the same topic by some new authority in the same field.

I shall give in the approximate order of the syllabus a few topics given in the reference books suggested in the Directions for Performing the Laboratory Exercises contained in the Syllabus for Physical Geography, issued by the State Education Department at Albany.

1 The *Nebular Hypothesis* as generally presented is given in Winchell's World Life in a very convenient form.

2 The *Planetesimal Theory* was studied at odd times for weeks from Chamberlain & Salisbury's Geology and presented in an address that would have been honored in any of the sections of the American Association for the Advancement of Science. I believe with the pupil that this piece of work was one of the most valuable things she did in her whole high school course. It was a labor for love of science.

3 Purely astronomical subjects are seldom chosen by my pupils but one girl especially interested along this line gave us from cyclopedias, Todd's *Astronomy*, etc. a very valuable paper on the "Moon."

4 With reference to the Sun I hope to get an interesting paper based on the Smithsonian reprint pamphlet on Solar Radiation, Davis — Meteorology, and Hann — Climatology.

5 " Why the Sky is Blue " is discussed in Davis etc.

6 Clouds have been studied from Ruskin — Modern Painters, volume 11, " On the Truth of Skies," and the United States Government cloud chart. No course in physical geography has been in vain if it teaches a lifelong interest in the clouds and an appreciation of their beauties.

7 *Climate* I generally have studied in connection with the topographic features of various countries and states so widely distributed over the world that the principal types will be illustrated. Every pupil should select *at least one country, state, city, or island* to show the interrelations between the climate, topography, manners, customs, principal products, and history.

Mill — International Geography may be taken as basis upon which Baedeker may be built. Partsch — Central Europe. Mackinder — British Isles, bulletins of the Bureau of American Republics, and Bartholomew — Atlas of Meteorology.

England, Ireland, Scotland, *Spain,* France, Germany, *Russia,* Italy, *Greece, Egypt, Palestine,* Mongolia, Japan, *Philippines,* Australia, Hawaii, Chili, Peru, Ecuador, *Columbia,* Jamaica, Cuba, — California, *Texas,* Florida, Virginia, New York, Ohio, Minnesota, Washington — San Francisco, *Mexico City,* Pekin, Madrid, Lisbon, etc. Comparisons of cities along the same parallel as *New York and Denver, Lisbon and Madrid.*

8 *Changes in climate* may be considered in the study of Lakes Bonneville and Lahontan — U. S. Geol. Sur. Bulletin — Ice Age. Croll — Climate and Time.

9 *Climate of New York State* — Turner in Tarr — Physical Geography of New York State.

10 *Climate of New York City* in the Annual Averages and Summaries of the Meteorological Observatory in Central Park.

11 *Life in the Sea,* Origin of Life, Sea Bottom in Smithsonian reprints, Hickson, Mill, etc.

12 *Mediterranean* — Smithsonian reprints, Suess (Reclus).

13 *Sea Level,* the Disturbing Effects of Land Masses thereon, and Effect on Gravity — Suess — Face of the Earth.

14 *The Deluge* is treated in an interesting way in Suess, but as yet I have not ventured to have it discussed in my classes, composed as are all of New York city public schools of pupils of many religions.

15 *Caves,* Ground Water, etc. Shaler — First Book in Geology.

16 *Life History of a River,* Russell — Rivers of North America.

17 *Niagara Falls,* Physiography of the United States and several reports published by the New York Museum, Niagara Commission.

18 *Lakes,* Tarr — Physical Geography of New York State, Dryer — Indiana Geography, Lakes *Agassiz, Bonneville, Lahontan* — U. S. Geol. Sur. Rep'ts, Lake *Passaic* — N. J. Rep'ts, Lake *Iroquois,* N. Y. State Rep'ts.

19 *Glaciers* are very popular subjects. Ball — *Astronomical Causes of an Ice Age, Glacial Phenomena,* Tyndale — Forms of Water. Russell — *Life History of a Glacier* in his Glaciers of North America, *Work of a Glacier* — Chamberlain and Salisbury — Geology, *Glacial Marginal Lakes,* Woodworth — Pleistocene Geology of Long Island. See above under Lakes also.

20 *Rocks of Manhattan* — Gratacap — Geology of New York City in connection with Diller — Study of Rocks.

21 *Clay,* a chapter in Ries — Clays of New York State, N. Y. State Mus. Bul. 35.

22 *Soils,* Handful of Soil — Cornell Nature Study Ser.

23 *Diastrophism, Vulcanism, Gradation* should be studied from Powell's articles in the Physiography of the United States. (Suess, etc.)

24 *Dislocations,* Suess, v.1.

25 *Volcanoes* is the first choice of the most pupils. Assign *Vesuvius, Pelee, Hawaii, Etna, Hecla* to various pupils. Refer to the geologies in stock.

26 *Stages of Denudation of Volcanoes,* Suess.

27 *History of the Palisades,* U. S. Geologic Folio 83 New York City.

28 *The Work of the Winds,* Chamberlain and Salisbury — Geology.

29 *Geographic Cycle,* Dryer — Physical Geography.

30 *Plains* — Tarr — Physical Geography of New York State.

31 *Plateaus,* (Powell's Colorado). Dutton in v.2 U. S. Geol. Sur.

32 *Mountains,* Lubbock — Scenery of Switzerland, Tarr — N. Y. Physical Geography, Chamberlain and Salisbury, etc.

33 *Shore Lines* —Avebury (Lubbock) — Scenery of England. Geike — Scenery of Scotland.

34 *Coral Islands* — and Coral — standard geologies.

35 *Mangrove* — U. S. Geol. Sur. An. Rep't 17.

36 *Harbors* — Shaler — Sea and Land, and in U. S. Geol. Sur. An. Rep't.

There are always many interesting questions about one's own neighborhood the investigation of which in the field or in what has been published adds enthusiasm and interest. I add a few that suggest themselves about New York city.

37 *How does it come that the Hudson River is where it is?*

38 Account for the *Harlem plain.*

39 Account for *Mount Morris.*

40 What agencies may have determined *the location of the depressions through the east bank of the Hudson* at Spuyten Duyvil, Inwood, Manhattan street and 129th street, and Canal street?

41 *Former Drainage of Manhattan Island* [Col. Waring — Half Moon Ser., Holt & Co.]

42 *Folds and Faulting Here.*

43 *The Malaria Map* and What it Shows.

44. 45 As a general summary it would be well to divide among several pupils the various chapters of Prof. Brigham's *Geographic Influence on American History* and Semple's *American History and Its Geographic Conditions.*

46 Romanes — Scientific *Evidences of Organic Evolution* lends itself readily to presentation in class and serves as an excellent means of correlating anatomy, paleontology, geology and other sciences with our subject. It is interesting, instructive and stimulating. Its discussion serves as a fitting conclusion to the term's work.

Section D — MATHEMATICS

SECONDARY MATHEMATICS FROM A COLLEGE STANDPOINT

BY H. E. HAWKES, YALE UNIVERSITY, NEW HAVEN, CT.

In a discussion of secondary mathematics from a college point of view, or in fact from any other point of view, it is essential that we have a clear understanding of certain principles by which we may determine what is of vital importance in mathematical teaching. Before attempting to discuss particular features of our subject, such principles must be presented.

Throughout the period of upheaval to which our curriculum has been subject in the last 20 years, mathematics has by common consent remained nearly stationary. The classics have been fighting furiously for continued prominence, the modern literatures and history are fighting for recognition. The absence of a severe struggle for existence on the part of teachers of mathematics has perhaps rendered less necessary an explicit justification of the place that the subject holds. When analyzed, some of the common arguments for the study of mathematics are seen to have very little force. When one is asked by parent or student to assign a reason why he should continue the subject, one is tempted to present the old familiar phrases, " mental training," " disciplinary study," from which the meaning has long ago vanished for many of us. The phrases still sound attractive, but are they convincing? Who could convince the teacher of Latin that better " mental training," whatever that may be, can be obtained from geometry than from Latin composition, or the teacher of history, that learning the multiplication table is more " disciplinary " than learning a list of dates?

We know what physical training is. We can experiment with different exercises, and determine by examination or measurement the effect of each on our muscles and bodily functions. The very expression, " mental training," assumes that the analogy between the life and growth of body, and that of the mind is a safe one on which to reason. This is of course far from the truth. Psychology has very little to tell us regarding the comparative effect of various studies on the mind; it has no means of measuring the relative value of a Latin lesson and of an algebra lesson in producing culture.

We must go deeper to justify either to ourselves or to others the important place held by mathematics in our educational system, We must determine what an education is. It will then be an easy matter to give mathematics its proper place, and to estimate rather closely the educational value of the various parts of the subject. Numerous excellent descriptions of the process of education have been given, and, when the terms employed are properly defined, many of them express about the same idea. Here is one that is slightly modified from a statement of Huxley. *To educate is to instruct the intellect in the facts and laws of nature — including men and customs as well as things and forces — and to fashion the affections and the will into a desire to move in harmony with those laws.* The term, laws of nature, should be understood in a very broad sense, and should include the laws that underlie the development of the arts, literature, and all fields of human activity.

This statement falls into two parts: (1) Instruction regarding facts and laws, as truths outside of and independent of the learner. (2) A personal appeal to the individual, not only to understand and appreciate those laws, but to make them a part of his own mental outfit, and to move in harmony with them. The first part is statics of education, the second the dynamics.

Let us now analyze the subjects in secondary mathematics, and estimate somewhat in detail their value. Consider first, plane geometry. It is an essential characteristic of a subject that we should admit into our schools that it teaches facts and laws which are of importance to our society. The most important facts taught by geometry are the rules of mensuration, by means of which the areas and volumes of all the simple figures in the world around us can be measured. There is perhaps no more effective means of holding the attention of the less competent members of a class in geometry than frequent reference to this aim. It appeals to any normal mind as a definite and worthy object of study, and its importance renders the more necessary a complete and working knowledge of those rules. It is this fact that gives the great pedagogical value to numerical problems worked out along with the proofs of the book theorems. In this way the student sees as he proceeds the application of his result to practical matters.

The law that is taught most effectively by geometry is the law of necessary relation — the fundamental principle that it is possible to arrive at the unknown through the known. It is most frequently by the study of geometry that the eyes of the mind are first unsealed to the light of rationality. The psychologists have long been familiar with the moral awakening of the child. I can recall distinctly a well directed punishment that was responsible for my own moral awakening on the subject of stealing. Before that time, stealing was for me a nonmoral activity — since that time, it has been immoral. The rational awakening of the mind is just as definite an experience as the moral awakening. The safe conduct of the youth through this crucial experience is of such tremendous educative importance that any subject that is effective in this direction should be certain of a fixed place in our curriculum almost regardless of its other qualities. That the study of plane and solid geometry is thus effective seems probable a priori. I have also collected a good deal of direct evidence that points in the same direction. We have seen, however, that geometry is far from depending entirely on this important quality for its value as a subject for study in our schools.

Let me add a word in regard to the light that this period of rational awakening throws on the order in which algebra and geometry should be taken up. Though no reliable data are available, it is pretty certain that this experience is of relatively late appearance in youth. I find, every year, boys in the freshman class who experience it in solid geometry, even after they have been thoroughly exposed to plane geometry. This indicates that algebra, where the acquirement of a technic is the all important result, should precede geometry, the latter being deferred to the maturer years, when the mind is more surely prepared for an appreciation of the subject.

As judged by the first part of Huxley's definitions of education, geometry seems worthy of a high place in our curriculum. Let us consider the effect of geometrical study in bringing the mind into harmony with the laws to which it has discovered itself subject. By following through the theorems in the textbook, the normal student becomes convinced of the authority of the law of reason — over the mind of the author. He has yet to bring his own mind into working harmony with this law. This he accomplishes through the study of original problems. Here the student can feel the demands of rational procedure. It is almost the joy of creation that he experiences in the solution of a hard original. Lip assent is no longer adequate — the mind must be in harmony with the law of reason.

In estimating the educative value of algebra, the question is at the same time simpler and more complex. Algebra is preeminently a subject for use. It is a tool. Its function in an education is covered by the first clause of Huxley's statement. The facts and laws that are taught center around the operations with numbers, or symbols for numbers. There is no great law that stands preeminent as in the case of geometry, to the mastery of which all energy must be directed. The subject of algebra is a necessary background for the study of geometry, physics and in fact all branches of exact science and technical training. Its function is more humble than that of geometry; its mission is to serve rather than to command; it plays the part of the Martha of science rather than that of the Mary. It is necessary to our curriculum in perhaps a broader sense than is geometry. The other subjects must refer to it, but the value of the subject for itself is by no means of so high an order as that of geometry.

The by-products of the study of both algebra and geometry, for instance, accuracy, good form, persistence may be dismissed with mere mention.

I wish now to go into a little detail in regard to certain vital points in the teaching of geometry. The principles that have been laid down should be of assistance in this discussion of particular questions. We undoubtedly agree that at present the student is so crowded with book work that must be covered that all too little time is left for that most important work of all, a systematic, progressive and careful training in the solution of original problems. Any relief that can be obtained from book work tends to greater efficiency there. Let us keep in mind that the explicit aim of the book work is the proof of the rules of mensuration of the circle and the polygons. The sooner and easier we can get these proofs, consistently with sound reasoning, the better.

First, let us consider the relation of the axioms to the body of theorems in plane geometry. The dictionary says that axioms are self-evident — the textbook in geometry often says the same thing. But how about theorems? May they not be self-evident too, even more clearly self-evident than the axioms? For instance, Euclid gives as his parallel axiom, " If two straight lines are cut by a third straight line, and the sum of the interior angles on the same side of the transversal is less than two right angles, then the two straight lines meet, and that on that side of the transversal where the sum of the angles is less than two right angles." He proves as a theorem that "the sum of two sides of a triangle is greater than the third side." Which statement I ask is more clearly self-evident?

No one would say that Euclid's parallel axiom is more self-evident than many of his theorems. Self-evidence is, then, not the distinction between an axiom and a theorem. As a matter of fact, Euclid knew what a geometrical axiom is better than his followers for many hundred years. He realized, as we do today, that the geometrical axiom is a statement that we take as the basis for the logical development of our geometry, and that self-evidence has nothing to do with it. We may assume many different sets of statements as axioms, and develop geometries from each of them. The geometries might differ in content to a wide extent, but would be in every case the logical consequences of their axioms. In recent years the attempt to find simpler axioms than those usually assumed has been very far-reaching, and we now know that a set of axioms for our geometry that comprises the fewest possible independent statements renders as theorems a large number of statements that we always tacitly assume in our textbooks, or else include in some more comprehensive axiom or definition. In order to push back the axioms to the fewest and simplest logically, proof must be given of theorems which would be included in a more extended set of axioms. In some of our common textbooks this tendency is noticeable. We often see the theorems, "All straight angles are equal," "All right angles are equal," and the like proved. I ask, what is the use? Didn't we think they were true before we proved them? Did the proof make us any more sure of their validity? The students all say, " Why, any fool knows that!" True they have been given an opportunity to use their reason, but there are plenty of theorems left that are not self-evident in which we can get practice in logic. It strikes the student as too much like getting out of a battleship to kill a mosquito. The geometrical intuition of elementary students is outraged by such theorems, and they certainly bring about a lack of interest in and respect for geometry. Such theorems do not give us any new facts, they do not teach the boy how to reason a whit better than the theorems that he considers worth proving, they certainly do not attune his mind to the verities of science, and they consume valuable time. The way out is very simple. So choose a body of axioms or assumed truths as to include all of those theorems that are self-evident. We know that we can't use the most fundamental geometrical assumptions as axioms even if we want to, since it would make the geometry unteachable. Why, then, should we strain so strenuously in that direction? Make as axioms statements that any one would accept as true in space without proof, and avoid those trivial theorems. This is not a matter that a teacher can be expected to carry out individually. It is one of the important points to keep in mind when selecting textbooks. In many schools a course in drawing or inventional geometry or some such subject precedes the study of geometry in which the pupil may become familiar with geometrical language, and through which these self-evident truths become indeed self-evident. This is of course a great help. I wish parenthetically to protest against the feeling that exists in some quarters that all the large colleges insist on this hairsplitting method of teaching geometry, which is alike unscientific and unpedagogical.

I wish now to say a few words about the theory of limits. During 10 years' experience in teaching geometry to students who have been in general carefully prepared by the best of teachers, I do not believe I have met a dozen who understood the theory of limits. This is not the fault of the students, nor of the teachers, nor entirely of the textbooks. The difficulty lies in the fact that we are trying to do something that can't be done. To give an average boy from 14 to 16 years of age a convincing sense that the proofs on limits are arithmetical in their essence, to train him to watch carefully the crucial point of the proof, namely that the difference between the variable and its limit can be made less than any assigned value is a task so out of the swing of the rest of the geometry that it is doubtful if it can be done with any degree of success even with textbooks that are beyond reproach. You recall that each of the theorems in the first four books of geometry that use the theory of limits are divided into a commensurable and an incommensurable case. Now to begin with, the incommensurable case enters to meet a mathematical rather than a practical difficulty. No draftsman or mechanic was ever embarrassed because he could not measure a line exactly $\sqrt{2}$ feet long. The proof of the commensurable case is sufficient to give mental satisfaction to any one in regard to the proof of any of those theorems. Even the fact that a regular inscribed or circumscribed polygon approaches the circle as a limit is evident after a few words of explanation.

Several ways are open to us. We may give enough time to the theory so that the students understand thoroughly a rigorous treatment of the subject. This would require much more time than could be spared for it, and probably could not be carried through in any length of time. We may continue to give the students the present proofs which they do not understand, and which are far from rigorous. If we recommend these proofs as rigorous, it is not honest; if we state that they merely serve to give mental satisfaction of the truth of the theorems, we surely fail, for they saw the truth of the theorem clearly enough from the commensurable case. The theory of limits obscures rather than illumines the truth to their minds. We may explain the existence of the incommensurable case as a mathematical difficulty, illustrate it, and state that as a rigorous treatment is out of the question at present, and that the proofs will be found — somewhere else. In this way we save time, the interest of the student and our reputation for scientific accuracy. Perhaps we shall decide to hear students flounder around over their heads in words a few years more before taking such a radical step. Perhaps the matter will not be settled in quite the way I have suggested, but one thing is clear. From every point of view that I am able to take, the theory of limits in elementary teaching seems a failure. If both secondary and college teachers suddenly discover that they agree on this point, the rest is simple.

To sum up then. The tendency in the teaching of geometry should be not in the direction of including more new matter, but rather of omitting the unessential, making possible the more thorough and complete mastery of the important educative elements in plane geometry.

WHAT EQUIPMENT IS NEEDED FOR THE EFFECTIVE TEACHING OF HIGH SCHOOL MATHEMATICS?

BY C. E. BIKLE, HORACE MANN HIGH SCHOOL, NEW YORK CITY

In considering the teaching of high school mathematics the first question to arise is, naturally, "What shall we teach?"

Teachers of mathematics in high schools are confronted at the present time by a peculiarly unsettled state of the curriculum. Two elements enter into this unrest: the constant effort everywhere to improve the arrangement of subject-matter, and the condition present in many instances, where the same class work must suffice for the students preparing for college and those whose education is to end with the high school.

The College Entrance Examination Board of the Middle States and Maryland has simplified matters here in the East, by defining pretty clearly the work required of "college preparatory" students. The system originated by this board marks a great advance in the method of managing the admission of students to college. But as Professor Thorndike points out in the *Educational Review* of May 1906,

> We may assume that the work which members of this board may hope to do, in making the connections between school and college rational in all respects, is more important than the admirable work already done in systematizing and simplifying the conditions of entrance examinations.

Now, what the mathematics of the high school shall be, is a problem which ought not to be determined by reference to college entrance requirements except in those schools which make preparation for college their main object; for no teacher will assert that the course in mathematics which prepares pupils for the ordeal of the college examination is the one best adapted " for the harmonious development of all the faculties."

In the *School Review* for January 1906 is an article by Prof. G. W. Myers, College of Education, University of Chicago, on " Mathematics in the (Chicago) University High School." In that school the mathematical faculty is attempting to arrange a course of study in which the related material of arithmetic, algebra and geometry shall be organized and associated. This is, of course, only a correlation of the mathematical subjects among themselves, but it is a sound method of procedure and one which commends itself to all teachers. It will result in giving greater mathematical power to the pupils, and will meet with the approval of the colleges. The plan seems to me much superior to that proposed by the Central Association of Science and Mathematics Teachers in the publications with which you are doubtless familiar.

Just what the reformed mathematics of the secondary school will become, is not yet determined, but the reform movement has been started and will without doubt be much advanced by the closer affiliation of the already existing associations of teachers of mathematics and science.

Teachers interested in this movement will find inspiration in books recently published in England such as Castle's *Manual of Practical Mathematics* published by Macmillan, and *A Course in Practical Mathematics* by F. M. Saxelby, published by Longmans, Greene & Co. The latter book was reviewed by Dr David Eugene Smith in the June bulletin of the American Mathematical Society. However, in the word I shall have to say about equipment for effective teaching I shall assume the curriculum which most of us are now using.

First in order in the equipment for the effective teaching of high school mathematics I should put the teacher. He must have not only scholastic attainment but the ability to teach. Dr Smith told you in his lecture of last evening what the preparation of the teacher should be. His point, that the young teacher should never lose sight of the fact that he must reach boys and girls, can not be too much emphasized. Some of you may have heard of the young man, a thorough scholar in mathematics, who when first confronted by a beginning class in geometry, assigned a lesson after this fashion: "Write a paper comparing your text with that of Euclid."[1]

Second in importance in the equipment for effective teaching stands the mathematical library of the school — books for teachers and books for pupils. I venture to say that to all of us, books are necessary for growth. However original an individual's method of thought, however fresh his interest in the body of subject-matter that he must repeatedly consider, the very fact of continued thought from his own viewpoint will work as surely for "staleness," as the same amount of the most commonplace routine. The possibility of keeping himself in touch with the ever varying views which new thinkers are bringing to bear upon the old problems is one service rendered by books to the teacher, whose work tends to lose a certain freshness through mere repetition.

Books will give in some measure to the teacher who lacks professional training the opportunity to acquire that wider knowledge which training has afforded to his more fortunate colleagues, while the teacher who has the most thorough preparation for his work must constantly prepare himself for the better work which will be required of him.

The mathematical library should be no less important to the pupil. The habit of consulting reference books has heretofore been made more of in other high school subjects than in mathematics. This is a mistake. Any pupil who is to pursue a mechanical or technical career, or, indeed, any one who is to do good work in mathematics later on, needs to get a glimpse of the field of mathematical literature, and to gain that "consulting habit" which will so simplify his later difficulties. A list of books recommended as a mathematical library for high and normal schools by the professor of mathematics of Teachers College follows:

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[1] In this connection it may be well to refer to an article by Dr Smith in the Proceedings of the National Educational Association, 1903. The title of the article is "Does th teacher's knowledge of a subject differ from the scholar's knowledge?"

A mathematical library for high schools and normal schools

The following list is prepared to answer a demand for information as to a few books suited to the needs of students and teachers. It is confessedly incomplete, the desire being to suggest a brief list of books that may, at least in part, be within reach of all high schools and normal schools. The prices are merely approximate, representing what a library has to pay after the usual discount is allowed. Textbooks have been excluded for obvious reasons, but the list should be supplemented by those American textbooks that have distinctive features or that have proved usable in a large number of schools.

I shall be pleased to give further assistance in recommending books, if teachers will write me. Foreign books may be secured through importers like G. E. Stechert, 129 west 20th street, or Lemcke & Buechner, 11 east 17th street, New York city.

DAVID EUGENE SMITH
Teachers College
Columbia University

1 For pupils and teachers, suitable for a high school library

ALGEBRA

Chrystal.	Algebra. 2 v. Macmillan $7.50
Fine.	Number System of Algebra. Heath $1
Phillips & Beebe.	Graphic Algebra. Holt $2
Nipher.	Introduction to Graphic Algebra. Holt 70c
Fine.	College Algebra. Ginn $1.50

GEOMETRY

Hall & Stevens.	Euclid's Elements. Macmillan $1
The Harpur Euclid.	Longmans $1.10
Casey.	Sequel to Euclid (an excellent exercise book). Longmans $1.10
Hocevar.	Solid Geometry. Lond. Black 60c
Henrici.	Congruent Figures. Longmans 50c
Manring.	Non-Euclidean Geometry. Ginn 75c
Row.	Geometric Paper Folding. Open Court Pub. Co. $1
Klein.	Famous Problems of Elementary Geometry. Ginn 55c
Wells.	Stereoscopic Views of Solid Geometry Figures. Heath & Co. $1

Heath's Mathematical Monographs. Heath & Co. (Four numbers 10c ea.)

MATHEMATICAL RECREATIONS

Abbott, E. A.	Flatland. Bost. Little, Brown & Co. 60c
Schofield, A. T.	Another World. Lond. Swan Sonnenschein. $1

(The above two books are popular works on the fourth dimension.)

Dodgson, C. L.	(Known in literature as Lewis Carroll, author of *Alice in Wonderland*)
———	Pillow-problems. Macmillan 75c
———	A New Theory of Parallels. Macmillan 75c
———	Euclid and His Modern Rivals. Macmillan $2
Hill.	Geometry and Faith. Lee & Shepard $1.25
Schubert.	Mathematical Essays and Recreations. Open Court Pub. Co. 75c
Ball.	Mathematical Recreations. Macmillan $1.75
Kempe.	How to Draw a Straight Line. Macmillan 75c

HISTORY OF MATHEMATICS

Fink.	History of Mathematics. Open Court Pub. Co. $1.50
Ball.	History of Mathematics. Macmillan $3.25
———	Primer of History of Mathematics. Macmillan 65c
Cajori.	History of Elementary Mathematics. Macmillan $1.50
Gow.	Short History of Greek Mathematics. Cambridge $3
Allman.	Greek Geometry from Thales to Euclid. Longmans $3.40
Smith.	Portfolios of Portraits of Eminent Mathematicians. 2 pt. Open Court Pub. Co. $3 ea., and a special part for high schools, $2

GENERAL

Conant.	Number Concept. Macmillan $2
Brooks.	Philosophy of Arithmetic. Phila. Sower, Potts & Co. $2.50
Saxelby.	Practical Mathematics. Longmans $1.85
Murray.	Practical Mathematics. Longmans 80c
Castle.	Manual of Practical Mathematics. Macmillan $1
Morris.	Practical Plane and Solid Geometry. Longmans $1
Richards.	Navigation and Nautical Astronomy. American Book Co. $1
Jones.	Mathematical Tables. Ithaca, N. Y. George W. Jones $1
Vega.	Complete Logarithmic Tables. (7 place). N. Y. Lemcke & Buechner $2.50
Johnson.	Theory and Practice of Surveying. John Wiley & Sons $4

Pence & Ketchum.	Surveying Manual. N. Y. Engineering News Pub. Co. $2
Crelle.	Rechentafeln, Lemcke & Buechner (Complete multiplication tables 1000 x 1000) $4.50
Cox.	Manual of the Slide Rule. N. Y. Keüffel & Esser 50c
Duncan.	Applied Mechanics. Macmillan $1

2 *Primarily for teachers*

ENGLISH

McLellan & Dewey.	Psychology of Number. Appleton $1.50
Smith.	Teaching of Elementary Mathematics. Macmillan $1
Young.	Mathematics in German Schools. Longmans 80c
De Morgan.	On the Study and Difficulties of Mathematics. Open Court Pub. Co. $1.25
Lagrange.	Lectures on Elementary Mathematics. Open Court Pub. Co. $1
Dedekind.	Essays on Number. Open Court Pub. Co. 75c
Burnside & Panton.	Theory of Equations. 2 v. Longmans $3.50
Clifford.	Common Sense of the Exact Sciences. Appleton $1.05
McMarry.	Special Method in Arithmetic. Macmillan $1

FOREIGN

(Approximate cost imported)

Ahrens.	Mathematische Unterhaltungen. Leipzig. Teubner $1.25
Lucas.	Récréations Mathématiques. 4 v. Paris. Gauthier-Villars 60c ea.
———	L'Arithmétique Amusante. Gauthier-Villars. $1.50
Holzmüller.	Elemente der Stereometrie. 4 v. Göschen, Leipzig, about $3
Cantor.	Geschichte der Mathematik. 3 v. (The Standard) Teubner $19
Laisant.	La Mathématique. Paris. Carre et Naud $1.25
Matthiessen.	Grundzüge der Algebra (Methods of solving equations). Teubner $2.50
Bourlet.	Algebra. Paris. Colin $1.50
Tannery.	L'Arithmetique. Paris. Colin $1.25
Henrici & Treutlein.	Lehrbuch der Elementar-Geometrie. Teubner
Mahler.	Ebene Geometrie. Leipzig. Sammlung Göschen 25c
Hadamard.	Géométrie élémentarie. 2 v. Colin, Paris $4

The third item in equipment includes what is generally called illustrative material or helps. The records left by ancient mathematicians indicate comparatively little of the equipment used by the early teachers. The surprising formulas given by Ahmes for the areas of the isosceles triangle and the trapezoid would indicate that the ancient Egyptians might also have been saved by a knowledge of squared paper. The approximation 3 for , given in I Kings, 7:23, and in II Chronicles, 4:2, would indicate that the Hebrew prophet's mathematical apparatus lacked that fundamental equipment, a piece of string.

Whatever the deficiencies in apparatus among the ancients, the modern tendency is rather in the direction of too many and too complicated appliances. The beginnings of geometry were made when conditions were simple. A figure drawn in the sand, under the open sky, served Thales to solve geometrical problems, and very little more is absolutely necessary today. In this simplicity mathematics has a certain advantage over those sciences in which apparatus plays such a prominent part that instruction may often degenerate into entertainment.

On the other hand certain objective material has an entirely legitimate place in relieving that tedium of the classroom which must be felt sometimes by all active bodied boys and girls. Full of humorous suggestion to the young teacher is the following extract from American history:

> John Smith, founder of Virginia, understood the nature of the red men, and was shrewd enough to appeal to it. Once when captured by a small band of Indians, he made the most of his little pocket compass, with its tiny darting needle . . . which so impressed the simple minded folk that, instead of putting him to death on the spot, they exhibited him in several villages and finally took him before the great war chief, Powhatan, for his disposal.

As a corollary one might add, "Don't bring your compass to class unless you are willing to have it handled."

It occurs to me that some of us could get the proper attitude toward the question of helps by recalling our experience as pupils. I hope that I speak for many of us when I say that counting came quite naturally to me through the illustrative material in my pocket. Did we ever have any trouble in counting the hundreds of marbles that came (by more or less questionable ethics) into our possession? On the other hand I sang with pleasure the multiplication table whenever the class was given the opportunity.

Fractions, though printed in small type, filled me with dread. There were no objective illustrations — simply rules in italics as to what you could do to and with them. I believe that my mental attitude toward fractions was much like that of the small boy, who, on being asked, after careful explanation and drill, what one could do to a fraction without changing its value, hesitated, and then ventured that one could let it alone. Abstract arithmetic gave me the pleasure derived from getting the answers in the book, but applications, such as mensuration furnished, were much more interesting.

Algebra was at first meaningless to me. The geometric representation of $(a+b)^2=a^2+2ab+b^2$, $(a-b)^2=a^2-2ab+b^2$, $(a+b)(a-b)=a^2-b^2$, and their application to numerical problems would have helped me greatly.

It is with geometry that the concrete object becomes indispensable. The fear entertained by some teachers that a figure made of sticks will prevent the pupil from appreciating the geometric figure seems to me groundless. Beginners in geometry can best get the meanings of definitions from figures that they themselves have constructed. Demonstrative geometry should be introduced by a course in geometric drawing, and the constant use of rule and compasses should be insisted upon. Very helpful at this stage are protractors of different sizes and the transit. By measuring an angle with protractors of different sizes pupils get a clear understanding of the meaning of "angle." By using the transit they are helped to appreciate a "geometric point" and to understand the statement "two points determine a straight line." With a start of this kind, pupils are soon able to dispense with illustrative material, and to proceed with pure demonstration.

When we come to solid geometry illustrative material is even more necessary. Yet here the "tendency to overdo" is apparent. I do not believe that the photograph of a set of bookshelves, or the shelves themselves, must be shown to a pupil in order that he may understand what is meant by a system of parallel planes. Excellent collections of models may be obtained from such German firms as B. G. Teubner in Leipzig and Dr Oskar Schneider (Leipziger Lehrmittel-Austaht), but comparatively few models of this sort are absolutely needed. Much simpler and more effective are models, constructed by pupils themselves, of knitting needles held together by modeling wax. Embroidery hoops may be so arranged as to give a good outline of a sphere. A fair sized slated sphere, caliper compasses, and a steel millimeter tape are excellent illustrative material for the teacher's table. (A cloth millimeter tape sewn upon a strip of whalebone or a section of clock spring is as useful, and much less expensive than the steel tape.) A good stereoscope and the views of solid geometry figures published by D. C. Heath and Company are interesting and of real assistance.

The equipment for trigonometry should, of course, include the transit, maps, and architects' plans of buildings. In the graphical study of spherical triangles good results are obtained by using the large sphere and the millimeter tape.

Since no high school course in mathematics is complete unless it touches, at least, upon the historical development of the science, and since the time that we may devote to this phase of the subject is so short, one of the most valuable aids a school can possess is a magic lantern. By judiciously chosen slides the pupil may see the development of (let us say) calculation. Pictures may be obtained ranging from that of the Chinaman with his shwanpan to a view of the actuarial department of one of our great life insurance companies, showing the extent to which computing machines are used in modern business. Portraits of famous mathematicians may be shown, and with the pupil's attention thus called to them may have more influence than when hung upon the walls of a classroom. The changes that have occurred in symbolism would furnish material for an interesting series of slides.

In brief, then, a school's equipment for the effective teaching of mathematics should be — a good supply of illustrative material, a good library and efficient teachers.

THE RELATION BETWEEN HIGH SCHOOL AND COLLEGE MATHEMATICS

BY H. E. WEBB, STEVENS INSTITUTE, HOBOKEN, N. J.

In true mathematical fashion, let us at the outset of the discussion define the terms involved. As is often the case in mathematics, our definitions will not afford any very clear concepts at once, but they will allow of some distinctions to be drawn later. By high school mathematics we mean mathematics as taught in high schools, and by college mathematics we mean mathematics as taught in colleges, the upper limit of the latter being rather indefinite. And it is safe to say that until a few years ago, there was little, if any, relation existing between the two, beyond the assumption on the part of the entrance committees of the college faculties that the candidates for admission had spent a little time in practice with simple algebraical expressions, and in memorizing some geometrical statements known as propositions, with stated proofs of the same. In fact it was considered more or less in the nature of flattery to dignify this preparatory work with the title of "mathematics." A secondary education was by no means prerequisite for college entrance, and indeed was regarded as of so little moment that colleges, particularly the larger institutions, came to disregard entirely the purpose and function of the secondary school, and to require of all candidates for admission, indiscriminately, the passing of an entrance examination. This state of affairs still persists in some quarters, and not long ago the president of a great university boasted that his institution was one of three in New England to adhere to it, the three constituting in his opinion, a legion of honor, for this reason. A very remarkable position this, in view of the host of teachers his institution has sent forth to secondary schools all over the country.

One result of this ancient system was and still is the necessity entailed upon the secondary teacher of spending considerable time, not in teaching mathematics, but in preparing classes for examinations, which may be wholly alien to the teacher's mode of thought and method of presentation, as well as to the pupil's mathematical experience. In many schools indeed, a goodly proportion of the time of the last or "senior" year is spent in analyzing, classifying and experimenting upon entrance papers of bygone days, in book form or otherwise. Note that the time thus spent is credited to mathematics, and not to experimental psychology! Apart from this line of study, carried on openly and above board, how much time is wasted by the teacher in a complete upset of his pedagogical principles, necessary in order to lay before the student certain types which statistical investigation has convinced him are likely to be called for?

The college entrance examination board has been an aid, and, as well, a source of confusion, in this unhappy situation. It has lightened the burden on the teacher of having not one, but six or eight college examinations to prepare members of one class for. But with its frequent changes in the personnel of the board of examiners, it has left the examination-mongers, including, perforce, most of us, in a high state of perplexity as to which way the kitten is going to jump next.

This may be desirable from some points of view, but it should be borne in mind that the high school mathematics of today contains at least twice the material which a teacher of superior abilities could present to a very receptive class in the time usually allotted to him; so the great problem before the teacher is one of selection, and here is the greatest difficulty. It is a matter not of topics or subtopics, but rather of the relative importance of this or that process, as viewed by the prospective examiner; or of the degree of complexity with which a few or many of these processes are interwoven in a particular case. The teacher must ignore entirely his own preferences and even his own pedagogical principles, no matter how well founded he may think them; and he may well be thankful if he is afforded a syllabus of topics, instead of the familiar statement: " Such as is generally covered by any standard textbook." As a matter of fact, the teacher is often guided largely by the textbook from which he thinks the examiner is likely to choose his questions.

Among the colleges, comparative standing in scholarship is often judged by the relative difficulty of the entrance examinations, and, presumably, by the relative difficulty of getting into the freshman class at all. A university, being a teaching body, might well boast of its ability to admit to its classes very poorly trained students, and to send out into the world very well educated men. Instead there has been for many years a notable rivalry among higher institutions as to which could unload upon the secondary school the most of its elementary, and consequently most difficult teaching, at the same time accepting the occasional clergyman, impecunious professional man, or self-supporting undergraduate as a satisfactory substitute. The College Entrance Examination Board has done much to better this state of things. But much more remains to be accomplished.

In the matter of grading the answer papers, what teacher in a secondary school has not anxiously awaited the annual store of surprises which comes in the return from the various colleges of the results of the examinations? The College Entrance Board has introduced a uniform and impersonal system of marking papers which has gone far to check that spirit of gambling with the chance of admission once common among prospective college students.

This much, merely because the examinations aforesaid have for years constituted almost the sole bond between high school and college mathematics, as we defined them.

As to the actual knowledge of elementary algebra and geometry requisite for progress in college mathematics, it is well known that very little of the information acquired by the student in his high school courses in those studies is ever in demand in later work. It is for the purpose of insuring preliminary discipline that college entrance requirements are laid down, and it remains yet to be elucidated in what sense examinations of the traditional sort can possibly serve as a test of mental discipline!

But there are assurances that a new era is dawning. College graduates and recipients of advanced degrees are continually invading the field of secondary work, while universities, in their summer schools and evening courses, are offering the best facilities for further study to those who were not so fortunate in their early training. The time seems to be near at hand when examination worship shall give place to a genuine recognition of the worth of the secondary school, and a willingness on the part of the college to accord to the secondary school its true place in the educational system of the country; the time when the high school diploma shall carry with it a full assurance that the courses outlined in the curriculum of the school have been satisfactorily covered by the holder, and that graduation from the school admits the graduate to all the rights and privileges appertaining to such standing, including admission to college.

Looking toward a closer and more rational relation between high school and college mathematics, as we have defined them, is the recent revival of interest in two lines of mathematical investigation: (1) The nature and principles of number and the nature of the four fundamental operations, and the character of algebraic forms, and (2) the foundations of geometry. These investigations are sure to have a direct influence on the teaching of secondary mathematics.

First of all, they have shown that the underlying principles of algebra and geometry offer a field for profound study, and are not to be taken for granted, as has often been done in the past, if mathematics is to secure its claim to be an exact science. Mechanical facility in the manipulation of algebraic and geometric forms is seen to constitute but a small part of the science and art of algebra and geometry. The capable teacher of secondary mathematics, then, is one who is well schooled in these underlying principles, and who is able to direct toward his subjects all the light of the most recent and scholarly mathematical thought. But obviously these fundamental doctrines are far beyond the comprehension of the high school student. And the great contribution which these lines of scholarly criticism have to offer is the clear demonstration that not a little of the much vaunted accuracy of the traditional high school mathematics, particularly in Euclid, or in American substitutes for Euclid, is rather nonsensical, and that the apparent stupidity of our "every schoolboy" has had a foundation in profound philosophic truth. How completely such truth may permeate his subconscious being it is difficult to say; this might bear investigating. Certainly many teachers have noticed that recent criticisms of ancient and accepted dicta in algebra and geometry have had their counterpart, in the questions of boys and girls at school.

The writer begs leave to offer a few such from his own personal experience:

a Consider the attitude of Russell, as well as that of Hilbert, toward superposition. Schoolboys fail to grasp the meaning of this process, and now they are not to be blamed for it. Occasionally a student does seem fully to comprehend it; but curiously enough such a student will generally find his further progress impeded by his persistent efforts to apply the method of superposition to all cases which involve congruences. This he may be permitted to do for a while, even at the waste of time and energy. But presently serious obstacles arise, and it appears that geometrical comparison and geometrical reasoning from the known to the (previously) unknown are utterly foreign to his mind. For this reason, considered practically, teachers have avoided the process of superposition wherever possible. The philosophical objections to the doctrine are closely analogous.

b The careless statement of the axioms is a fruitful source of difficulties to high school students. For example, they often undertake to add congruent figures to congruent figures (by annexation) and thereby show the results to be congruent. And it will be seen that this difficulty does not lie wholly in the misuse of the word "equal."

c The usual treatment of limits as given in modern textbooks on geometry is a gloomy fog to the teacher. To the student it is an impenetrable jungle, and his chief purpose at that stage of his work is to get around it gracefully. Verbal memory usually comes to his rescue.

d Teachers of physics and chemistry complain that students who come to them from the mathematical work in high schools are quite unfamiliar with variation and ratio and proportion. It is well known that the definitions of ratio and proportion, as set forth by most teachers and in most textbooks, beg the question completely.

e The attempt on the part of the teacher to gloss over the serious logical error of the hypothetical construction often costs the student his confidence in the logic of geometry.

f The difficulty which the beginner experiences with negative, fractional and zero exponents in algebra is oftener than not due to the failure on the part of the teacher (or his book) to impress on the pupil's mind the fact that the so called proofs really constitute extensions of the term "exponent." Otherwise these demonstrations seem to him of a piece with proofs that 1=2, and that all triangles are isosceles.

And so on *ad libitum*. In all these cases we are touching on matters, the exact and detailed statement of which are beyond the high school pupil's powers of comprehension, while the errors are clearly, or at least dimly, within his powers of discernment. From this consideration it must appear that a knowledge of mathematics, as is true of other sciences, must begin in the middle and proceed both ways; that many of the so called fundamental principles, as set forth to the students in secondary schools, are really not fundamental at all, but arise from notions far more general or abstract, and altogether too abstract to be taught to the beginner. Whence it follows that it is the work of the college to teach doctrines which are truly fundamental, leaving it to the secondary school to familiarize the student with methods of procedure, analytic and synthetic, with the terminology of the subjects, and with simple practical applications. This has more especial reference to beginning algebra and geometry. It would appear also that the secondary school might make incursions into the domain hitherto reserved for the colleges — analytical geometry, and higher algebraical equations, as well as trigonometry. (We might even add, some work in substitution groups!) In any case, the border line should be indicated not by the character of the subject-matter, but by the relative difficulty of the problem, or the abstruseness of the underlying principle, or the complexity of the processes involved. The calculus, for example, would then belong to the college, not because it is calculus, but because it is difficult.

Efforts have already been made to bring about earlier a familiarity with coordinates and the relation of curve and equation. This is usually done under the title of graphs or graphics, as if analytical geometry were something else and sacred. The syllabus of the College Entrance Board has included under higher algebra the theory of equations, and simple operations with determinants, and complex quantities, while at the same time it leaves almost the whole matter of series to the college, where it belongs. This step, a long one in the right direction, has been generally indorsed by schools and colleges.

Now let the board take a further step in advance, and set limits to the complexity of fractional expressions, of expressions with literal indexes, of quadratic equations, of fractional equations, and of symbolical expressions in general, as algebra is to be taught in secondary schools. Let it set the seal of its everlasting disapproval on the dog and fox business, on the question of the age of Ann and John under very trying conditions, on marvelous purchases of lead pencils or chestnuts, and on the utter moral depravity of A and B, who gamble desperately. Let teachers unite in a sincere effort to convince the rising generation that it is possible to solve an equation for some other letter of the alphabet besides x, y, or z. Let there be many other reforms too numerous to mention, but all in the direction of common sense. And let us not expect from the high school student any very profound knowledge of the nature and character of number, or of the demonstration of the validity of processes with fractional and negative exponents, or of the meaning of infinity, or of mathematical induction, or of the character of a series. Why should not the College Entrance Board, or some other board whose opinion is as highly valued among colleges and schools, lay down a series of geometrical postulates upon which to build up the high school geometry? Let the board look only to their consistency, and leave to the college investigators the question of their ultimate character as axioms. Let it go further, and distinguish between two classes of propositions, those deduced from the postulates by so simple a process that formal proof is unnecessary for high school students, and others requiring formal demonstration. Let it be understood that the high school student is to be held responsible for the demonstration of this last named class of propositions only, except for simple exercises limited strictly to the principles laid down in this syllabus, and for numerical problems having a like dependence. And let the high school student consider himself excused from the customary abstractions concerning superposition, incommensurables, limits, and lines intersecting at infinity; and also from such proofs as those that right angles are equal, that two circumferences internally tangent are nonconcentric, etc. Few would mourn the elimination of that highly cumbersome method of computing π which usually adorns Book 5.

We have seen that many of the most elaborate demonstrations with which we are familiar contain tacit assumptions which, when once stated, are positively offensive to the spirit of geometric research; that textbooks are crammed with hypothetical constructions, and even with hypothetical definitions; and that the students are given regular courses in straining at logical gnats and swallowing camels of inconsistency. And yet high school teachers are met constantly with the statement that many of the students sent by them to college fail to grasp the "underlying principles" of geometric science. To which the students may well reply with the respectable maxim about doctors disagreeing.

If they please, let colleges require for entrance the simple processes not only of trigonometry, but of analytical geometry. Yet it would obviously be absurd to demand a very profound knowledge of either of these sciences. Above all, let both examiners and teachers remember that nearly every beginner develops his mathematical system by a series of types of process, rather than by the direct application to particular cases, of general principles, as that term is now understood. The criterion of excellence should be the ability to reason logically in the terms of mathematics, and the possession of sufficient mathematical imagination to lead the student into paths to him new and untried. Let the examinations, since there must be such, be thorough and searching, but let the questions be strictly limited to the applications of principles laid down in the syllabus, in a manner not too complex. In other words, let it be *easy*, if a knowledge of principle and method is presupposed. But by "principle" is meant here a well defined logical mode of procedure, rather than an abstract fundamental truth.

"Algebra through quadratics" and "plane and solid geometry" are excellent titles for college courses wherein the student may learn to state and to develop in abstract terminology the principles in accordance with which he has been working during his preparatory course. Something similar to this exists in various departments of ancient languages in colleges, where students of Latin or Greek are administered thorough courses in grammar and composition, usually accompanied by vitriolic remarks on the part of the head of the department concerning the incapacity of the average high school teacher. The plan is as excellent as the remarks are unjust. The statement of a principle must both precede and follow its application: it must precede, to give unity and stability to the work, and it must follow to be thoroughly understood.

If it is objected that easy entrance examinations would flood the freshman classes with incompetents, there is only one reply: that graduation from a high school or academy of recognized standing should constitute an additional requirement, and that a departure from this rule in a particular case should be made only upon the recommendation of some officer of instruction appointed to examine into the matter. The general examinations should be directed toward the school rather than toward the students as individuals. The writer has often wondered whether better results could not be obtained if high school teachers, rather than students, were summoned each year before a college entrance examining board to set forth their mathematical, classical, linguistic or scientific attainments.

Perhaps, to even matters up, the presidents of the universities might be called upon to take their own examinations now and again!

In all seriousness, few who are not actually engaged in secondary teaching realize that the teacher is burdened with a triple tyranny — the college, the textbook, and the program committee. Much of his time must be spent in bringing these three elements into some sort of harmony. Of academic freedom he knows nothing, except by hearsay or in dreams. Examinations for entrance into *his* school are absurd. He must take his material as he finds it. Parents expect him to take in hand children who are often unwilling, unused to any sort of mental self-control, or densely stupid; and he must not merely afford them opportunities for study, but he must "make something of them." And when in addition to this he must cover twice or three times the ground that was originally intended when the four year high school course was laid down, and must follow closely the lines of one textbook, the problem is well nigh insoluble. He may consider himself fortunate if, as is sometimes the case, his textbook is one with which he is in hearty agreement, and which allows of sufficient latitude to permit such minor changes in his courses as his classes from year to year may demand.

Many teachers in the face of these difficulties have lost sight of one real value of mathematics to the extent of declaring that only such work should be given in high schools as the student is likely to apply in his scientific work thereafter. This suggestion may well give us pause, but not to yield the point that in mathematics, as nowhere else, is the student taught of truth as a necessity of his own mental structure, and not as an emanation from the authority of his superiors.

In brief, to establish a relation between college and secondary mathematics which is real and not superficial, let there be on the part of the college a recognition of the worth of the secondary school as an institution of learning, and of the secondary school teacher as an instructor and as a scholar. Let the teaching of sec-

Section D — MATHEMATICS

RECENT TENDENCIES AND OPEN QUESTIONS IN THE TEACHING OF ELEMENTARY GEOMETRY

BY W. BETZ, EAST HIGH SCHOOL, ROCHESTER, N. Y.

To any but a very indifferent observer it is evident that we are in the very midst of an unprecedented development in the teaching of elementary mathematics. The present reform movement appeared with such suddenness that we are still wondering how it all happened. In a few years numerous associations of teachers of mathematics have been organized all over the country, many papers have been written, and progress seems to be the watchword on all sides. And yet, many factors have combined to bring this about. In the valuable report of the committee on the correlation of mathematics and physics in secondary schools issued by the Central Association of Science and Mathematics Teachers, these new impulses are attributed to the following sources: (1) theoretical pedagogy, (2) the natural sciences (laboratory methods), (3) modern industrialism, (4) engineering and scientific and mathematical research.

I can not here undertake to review the history of the movement. I must refer to the report of the British Association Committee concerning its meeting at Glasgow, 1901, and to the now famous presidential address of Professor Moore of December 1902, also to numerous articles in *School Science and Mathematics*, the *School Review*, and other educational publications.

Now, granting the existence of a renewed interest in questions of elementary pedagogy, we may proceed to consider what has been accomplished so far.

The immediate important effect of the new movement has been a complete stirring up of every progressive teacher of mathematics. It has become necessary for him to examine more carefully than ever the why, what and how, of his subject.

Aim. In the first place, as regards the aim of geometric teaching, it is quite apparent that the one-sided theory of mental discipline is being modified. Some of the New England teachers of mathematics, for example, in their latest report [1906] state with the greatest emphasis that the utilitarian point of view must not be ignored. Mr J. P. Clark's paper contains this passage: "It is this practical value of the subject around which its supporters must rally in this industrial age, and it is our business today to discover how real this value is, and to how great an extent it is understood and appreciated by educators and by the general public." Again and again we are told that we have simply been giving our pupils a mass of tools, but have not secured their legitimate use. We are said to have forced upon the student mere mathematical verbiage, but to have studiously avoided natural channels of expression. It looks as though this separation of theory and practice were about to be abandoned.

Our ideas of rigor are also undergoing a change. Now, the school certainly does not wish to undermine the proverbially rigorous character of mathematics. We want all the rigor of which the learner is capable, but nothing more. A proof that is not appreciated by him as such has no pedagogic value. This opinion, long held by a few, is meeting with more general recognition. The New York High School Teachers Association, for instance, though apparently adhering more firmly to the ideal of mental discipline, appointed a "committee on limits" which recommended "that the proofs by the theorem of limits in the incommensurable cases arising under (1) ratio of central angles, (2) sides of a triangle cut by a line parallel to the base, (3) ratio of areas of rectangles, should be presented by the teacher with such completeness as he may deem expedient, but the reproduction of such proofs in formal examinations for advanced standing should not be required."

The school must use a broader foundation than the accomplished specialist. Professor Perry's extreme views on this point are too well known to require rehearsal. The following quotation is characteristic: "Our mathematicians are spending their time now in proving all sorts of things to be doable which the plain man knows to be doable, which the plain man does without getting preliminary permission.— Things assumed as axiomatic by Kelvin and Stokes are now being proved." Professor Moore, commenting on these ideas, says: "Perry is quite right in insisting that it is scientifically legitimate in the pedagogy of elementary mathematics to take a large body of basal principles instead of a small body, and to build the edifice upon the larger body for the earlier years, reserving for the later years the philosophic criticism of the basis itself and the reduction of the basal system." And again he says: "Indeed, for the purpose of elementary education our current deductive geometry is of the nature of a fetish, to be abandoned in favor of a geometry built on a richer system of geometric axioms, etc."

We may have to revise our aim, then, to the extent of (1) not forcing upon the learner material that is beyond his comprehension, (2) making the subject more interesting by restoring the union of theory and practice, (3) calling into play the greatest possible amount of self-activity on the part of the student.

Subject-matter. Without question one of the most noteworthy features of the present reform movement is the final disavowal, even in England, of grand old Euclid as an instructor of the young. While there is full recognition of the great qualities of the ancient master's work, some of the foremost mathematicians agree that from the standpoint of the school its defects exceed its merits. Their criticisms are directed against Euclid's system and method. Euclid's propositions are arranged logically, but not pedagogically. There is no direct connection between them, and the learner must depend on his verbal memory for their mastery. The dogmatic form of the *Elements* is severely criticized. A proposition is stated as a fact and is then proved elaborately. The pupil simply verifies what someone has done for him. His initiative is thus almost completely ignored. And these fundamental defects are only palliated by the mass of "riders" or "originals" usually appended to the text.

For many years more or less successful attempts have been made to modernize Euclidean geometry. It must be admitted that the task is a stupendous one. Recently, these efforts have been complicated by the appearance of various fusion movements and by the tendency to introduce the notions of modern geometry.

Some decades ago the theory was seriously advanced that the separation of plane and solid geometry was arbitrary and should be abandoned. This idea, which is probably an outgrowth of the pedagogy of Pestalozzi and Fröbel, and which has much to recommend it, is at present represented by such men as Méray in France, Ingrami in Italy, Holzmüller and many Herbartians in Germany.

A much more serious fusion is being tried in our own country. Some of our western colleagues are advocating nothing more or less than the complete unification of pure and applied mathematics. Professor Moore, in the address referred to above, said: "The fundamental problem is that of the unification of pure and applied mathematics. If we recognize the branching implied by the very terms 'pure' and 'applied,' we have to do with a special case of the correlation of different subjects of the curriculum, a central problem in the domain of pedagogy from the time of Herbart on.

In this case, however, the fundamental solution is to be found rather by way of indirection by arranging the curriculum so that throughout the domain of elementary mathematics the branching be not recognized.— Would it not be possible to organize the algebra, geometry, and physics of the secondary schools into a thoroughly coherent four years course comparable in strength and closeness of structure with the four years course in Latin?" He is careful to say, however, that all this must come by way of evolution from the present system, not as a revolution of that system. For a more complete discussion of the correlation of mathematics and physics I must refer to Prof. J. McMahon's detailed account before this association a year ago. It is greatly to be feared that under existing conditions such a unified course, unless conducted with the utmost care by teachers of the broadest possible training, will give the student only fragmentary and incoherent glimpses.

Nevertheless, although we take a more conservative stand in the East, there is even with us a decided tendency away from the rigid compartment system. Evidently our idea is not to unify but to correlate more intimately the various branches of pure mathematics, and in doing this to use all *convenient* and *readily understood* illustrations from the realm of applied mathematics. And it is the graphic method in algebra that is furnishing the most natural connecting link between algebra and geometry. As Prof. F. E. Nipher puts it, "the study of algebra and geometry as wholly distinct subjects having no relation to each other, gives to the pupil a false idea of the intellectual situation of today." The continuity of algebra in the curriculum is beginning to concern us more seriously. This is indicated by Prof. A. L. Baker's paper in the report of the New York teachers. Correlation in such form should find our support. Also, that we need to vitalize algebra and geometry along the line of more attractive applications not necessarily all of a utilitarian form, there can be no doubt. This conception, rather than that of the Chicago platform, seems to be in the mind of Prof. F. Klein and his followers.

An equally difficult question is that of introducing modern geometric notions into the school. Few of us have gone beyond the giving of a few isolated propositions in the form of an appendix. Here, again, we do not wish a revolution, but a gradual transition.

Foundations. It is easy to understand why at this period of unrest there should be such a remarkable interest in the foundations and in the history of mathematics. Indirectly this field of investigation is an outgrowth of the doctrine of evolution in the biological sciences. It is extremely fascinating to trace a theory to its origin and to examine its validity. And so we have the critical writings of Peano, Veronese, Enriques, Pasch, Hilbert, Killing, Poincaré and many others. Each year, too, adds to our fund of historical information. This historical critical spirit has extended our horizon enormously. It has given us non-Euclidean geometries and hypergeometry. We realize, as we never did before, that in a certain sense we can get out of a system only what we put into it.

Probably another generation will elapse before all these ideas shall have been absorbed and utilized. Years ago Prof. Simon Newcomb said: "The mathematics of the 21st century may be very different from our own; perhaps the schoolboy will begin algebra with the theory of substitution groups, as he might now but for inherited habits." In geometry we shall probably not see again a system at all comparable with Euclid's. Prof. G. A. Miller says: "Whether our critical age will produce a work which, like Euclid, will serve as a model for millenniums can not be foretold, but it seems certain that works which can stand the critical tests of this age will stand the tests of all ages." We shall continue to welcome good textbooks, but shall use these rather as suggestive outlines. The teacher will be given greater latitude as to subject-matter and he will develop not somebody's particular geometry, but simply geometry.

Method. American teachers have been justly criticized for their lack of interest in questions of method. We seem to depend on a kind providence for the correction and undoing of our pedagogical errors. Such a condition is very deplorable. It is very gratifying, therefore, to notice an improvement in that direction. This is proved by the very existence of the numerous mathematical associations recently organized in our country.

One thing is becoming quite clear. The learner must take a creative, not a reproductive attitude toward his subject. He must feel for himself the delight that comes from independent discovery. That much the laboratory method has taught us very forcibly. The instructor is to be, not the self-appointed dictator or lesson-hearing automaton, but the intelligent guide in the pupil's mental laboratory. Under this guidance the geometric edifice is to be gradually constructed, every element in it being furnished by the self-active cooperation and even initiative of the class.

We are also beginning to believe in the necessity of a preliminary course in geometry, variously called observational, experimental, introductory, practical, constructional. One reason for the many failures we have is the crowding of too many new ideas into a short period of time. The beginner should become gradually familiar through individual experience with the most important geometric forms before demonstrative geometry sets in. In accordance with this view some of the best schools are giving a preparatory course requiring a good deal of observing, drawing and measuring. Here, too, squared paper furnishes an invaluable aid. In the language of Professor Moore, graph paper is about to be canonized.

Finally, I have noticed with very great interest the increasing amount of attention that is being given to the genetic method. Professor Young of Chicago has done much to introduce it into American schools. It seems to be saturated with the true laboratory idea. From personal observation of it in German schools and from years of experience with it in my own classroom, I can recommend it most heartily.

Conclusion. In conclusion it may be said that the new situation, while it will affect our textbooks somewhat, concerns first and last the teacher. It will force the teacher to become a true artist. No one person, however, can expect to cope effectively with all these difficulties. What we need above all is active cooperation. If all the mathematical societies, now isolated, could be filled with the common aim of joint investigation and interchange of results, the outlook for the mathematics of the 20th century would be indeed glorious.

AMERICAN FEDERATION OF TEACHERS OF THE MATHEMATICAL AND THE NATURAL SCIENCES

BY C. R. MANN, UNIVERSITY OF CHICAGO

In accordance with the call, issued by joint action of a committee of the American Society of Teachers of Mathematics and the Natural Sciences and one of the Central Association of Science and Mathematics Teachers, a meeting of delegates of a number of associations was held in New York on December 27, 1906, for the purpose of discussing the formation of a federation of associations of teachers of science and mathematics. A roll of the meeting was taken, and it was found that there were present 27 delegates, representing 7 associations as follows: Association of Mathematics Teachers of the Middle States and Maryland, 9 delegates: New York State Science Teachers Association (mathematics section), 6 delegates: Central Association of Science and Mathematics Teachers, 5 delegates: Association of the Teachers of Mathematics of New England, 3 delegates: Association of the Teachers of Physics of Washington city, 2 delegates: Missouri Society of Teachers of Mathematics and Science, 1 delegate: New Jersey State Science Teachers Association, 1 delegate.

Prof. T. S. Fiske of the Association of Mathematics Teachers of the Middle States and Maryland was elected chairman of the meeting, and Prof. C. R. Mann of the Central Association of Science and Mathematics Teachers was made secretary.

After some preliminary discussion, it was, on motion duly seconded, unanimously

Voted, That it is recommended that there be formed, by the various associations of teachers of science and of mathematics, an American Federation of Teachers of the Mathematical and the Natural Sciences.

The question of the form of the organization was then taken up. Two different forms were proposed: one, that of a single society of teachers of mathematics and the mathematical sciences, the membership to be limited to associations that publish literature and reports; the other, a rather loose federation of all associations of teachers of either mathematical or natural sciences, the membership being limited to associations that have more than 50 members. The first of these forms was that adopted by the American Society of Teachers of Mathematics and the Natural Sciences at the conference held at Asbury Park in 1905. The latter form was proposed by the Central Association of Science and Mathematics Teachers.

In the discussion of this question, the latter form of organization was shown to be less formal and more flexible and to interfere less with the individual activities of the associations. Because this form of federation appeared to furnish the necessary basis for a first step toward a more complete organization, and because it was considered advisable that associations not represented at the meeting should have a voice in the final decision, it was, on motion duly seconded, unanimously

Voted, That the form of organization proposed by the Central Association of Science and Mathematics Teachers in the printed circular issued by them be tentatively adopted for the coming year, the final form of organization to be decided at the next meeting.

No officers were elected; but an executive committee, which should look after the interests of the federation for the next year, was elected as follows: T. S. Fiske, Columbia University, *chairman;* C. R. Mann, University of Chicago, *secretary-treasurer;* H. W. Tyler, Massachusetts Institute of Technology; R. E. Dodge, Teachers College, New York; F. N. Peters, Kansas City High School.

On motion duly seconded, it was

Voted, That this executive committee have power to fill vacancies and to add to its membership by unanimous vote.

On motion, the meeting adjourned, subject to the call of the executive committee.

MEMBERS 1907

When the name of an institution includes the name of its town or city the latter is not repeated. Where no state abbreviation is given, New York is to be understood.

Aiken, J. Hawley, 3 Clinton pl. Saratoga Springs, High School
Arey, Albert L., Girls High School, Brooklyn
Atkinson, George F., Cornell University, Ithaca

Bardwell, D. L., superintendent of schools, Borough of Richmond
Barrows, Franklin W., 1364 Michigan st. Buffalo
Beach, Grace B., Normal College of the City of New York
Bean, Charles M., Pulaski High School
Beers, Everett J., 50 Lafayette av. Geneva, High School
Bennett, William M., West High School, Rochester
Bentley, Gordon N., University of Tennessee, Knoxville, Tenn.
Benway, Mabel R., North Tonawanda High School
Betz, William, East High School, Rochester
Bigelow, Maurice A., Teachers College, New York
Binns, Charles F., New York State School of Clay-working and Ceramics, Alfred
Bishop, Irving P., State Normal School, Buffalo
Bogert, Marston T., Columbia University, New York
Bond, W. E., State Normal School, Potsdam
Boniface, Sister M., Nazareth Academy, Rochester
Bradley, Elizabeth L., Troy High School
Bradley, Theodore J., Albany College of Pharmacy
Brigham, A. P., Colgate University, Hamilton
Bryant, Frank L., Erasmus Hall High School, Brooklyn
Bullard, W. G., 613 S. Crounse av. Syracuse University
Burgin, Bryan O., Albany High School
Burlingham, Gertrude C., Binghamton High School
Butler, Alfred M., Schenectady High School
Byrnes, Esther F., Girls High School, Brooklyn

Callahan, E. B., Little Falls High School
Campbell, Daniel R., Rome High School
Campbell, Jessie R., West High School, Rochester
Carpenter, Ada M., Couch and William st. Plattsburg
Carroll, Anne L., State Normal School, Plattsburg
Case, L. V., Washington Irving High School, Tarrytown
Cate, Eleazer, 15 Harcourt st. Boston, Mass.
Cattell, J. McKeen, Garrison-on-Hudson
Chester, W. M., Colgate University, Hamilton
Churchill, Edmund P., Washington Irving High School, Tarrytown
Clark, Mary Augusta, Washington Irving High School, Tarrytown
Clement, Arthur G., Education Department, Albany
Clendenin, W. W., Wadleigh High School, New York
Cobb, Charles N., Education Department, Albany
Comstock, J. H., Cornell University, Ithaca
Corant, O. P., 70 5th av. New York
Cooley, LeRoy C., Vassar College, Poughkeepsie
Cornish, R. H., Wadleigh High School, New York
Cornish, William A., State Normal School, Cortland
Crawford, A. Myrtella, Central High School, Buffalo
Curtiss, Harriette A., Sodus

Dann, Mary E., Girls High School, Brooklyn
Davis, William H., Elmira Free Academy
De Groat, H. DeW., 11 Linden av. Brooklyn
Denham, Henry H., Commercial High School, Syracuse
Dithridge, Louise M., 42 Lorillard pl. New York
Dodge, Charles W., University of Rochester
Dodge, Richard E., Teachers College, New York
Dunham, Frank F., Canisteo High School
Dunn, Joseph G., Adelphi Academy, Brooklyn

Eddy, Walter H., High School of Commerce, New York
Elliott, Arthur H., Laboratory Consolidated Gas Co., 21st st. and Avenue A, New York
Emmons, Fred E., Olean High School

Failing, Wilson R., Port Chester High School
Farnham, Amos W., State Normal School, Oswego
Fitsworth, Waldo, Alfred Academy
Folsom, Frances L., Technical High School, Buffalo
Forbes, Charles, Columbia University, New York
Ford, E. E., Le Roy High School
Fowler, G. W., Little Falls High School
Freley, J. W., Wells College, Aurora

Gage, Simon H., Cornell University, Ithaca
Gary, Lester B., Central High School, Buffalo
Greene, W. J., South Glens Falls High School

Hahn, Clarence W., High School of Commerce, New York
Hale, Albert C., Boys High School, Brooklyn
Hall, James H., Syracuse High School
Hallock, William, Columbia University, New York
Hancock, W. J., Erasmus Hall High School, Brooklyn
Hargitt, Charles W., Syracuse University
Hargitt, George T., 909 Walnut av. Syracuse High School
Harris, C. Everett, East High School, Rochester
Hawkes, H. E., Yale University, New Haven, Ct.
Hayner, B. A., Canandaigua High School
Henderson, Royal L., Nyack High School
Herrick, Lillian B., Elmira Free Academy
Hersey, C. Brooks, Masten Park High School, Buffalo
Hine, Lewis W., Ethical Culture School, New York
Hodgdon, F. C., 70 5th av. New York
Hopkins, Rupert H., Curtis High School, West New Brighton
Hopkins, T. C., Syracuse University
Howes, H. L., Cook Academy, Montour Falls
Hudson, George H., State Normal School, Plattsburg
Huested, F. P., Albany High School
Hunt, Arthur E., Manual Training High School, Brooklyn
Huntington, F. W., Erasmus Hall High School, Brooklyn

Jameson, J. M., Pratt Institute, Brooklyn
Jaquish, Ben M., 681 E. 21st st. Brooklyn
Jenks, L. E., Ogdensburg High School
Jewett, Franklin N., State Normal School, Fredonia
Johnson, Julius M., Morris High School, New York
Jones, Eliza J., 182 Madison st. Brooklyn
Jones, H. B., Binghamton High School

Kelly, Henry A., Ethical Culture School, New York
Kemp, James F., Columbia University, New York
Kenyon, O. C., Syracuse High School
King, Cyrus A., Dewitt Clinton High School, New York

Kingsley, Clarence D., Manual Training High School, Brooklyn
Kirchwey, Clara B., Teachers College, New York
Kirkwood, J. E., Syracuse University
Kittredge, R. J., 446 W. 7th st. Erie, Pa.

Lamson, F. L., University of Rochester
Langworthy, William F., Colgate Academy, Hamilton
Lee, Frederic S., Columbia University, New York
Lee, Glenn M., Cook Academy, Montour Falls
Lennon, W. H., State Normal School, Brockport
Linville, Henry R., Dewitt Clinton High School, New York
Lockwood, Cornelius W., Newburgh Academy
Loeb, Morris, 273 Madison av. New York University
Logan, Mrs Mary C., Lyons High School
Lovell, Thomas B., Niagara Falls High School
Lyon, Howard, State Normal School, Oneonta

MacDowell, Frances, Watkins High School
McKay, John S., Packer Collegiate Institute, Brooklyn
MacKenzie, Mary D., Saratoga Springs High School
McMahon, James, Cornell University, Ithaca
McRae, Frances E., Horace Mann School, New York
Mann, C. Riborg, University of Chicago
Mann, Warren, State Normal School, Potsdam
Marcella, Sister M., Nazareth Academy, Rochester
Martin, Jennie T., Central High School, Buffalo
Maury, Mytton, Hastings on Hudson
Mellin, Calvert K., Central High School, Buffalo
Merrell, William D., University of Rochester
Merritt, E. G., Lafayette High School, Buffalo
Metzler, W. H., Syracuse University
Miller, Gertrude, Penn Yan Academy
Minchin, Howard D., University of Rochester
Moore, J. C., Cattaraugus High School
Moore, Katherine R., Penn Yan Academy
Morrey, William T., Morris High School, New York
Morrill, A. D., Hamilton College, Clinton
Morse, Charles F., Dewitt Clinton High School, New York
Morse, H. L. F., Troy High School

Naughton, John A., Albany High School
Newman, Hugo, Public School 33, The Bronx, New York
Nichols, Edward L., Cornell University, Ithaca

O'Brien, Abigail, Watertown High School
O'Neill, Everett, Education Department, Albany
Osborn, Henry F., Columbia University, New York
Overacker, Minnie L., Syracuse High School
Overton, Frank, Patchogue, L. I.
Owen, F. T., State Normal School, Potsdam

Paddock, Bertha L., Franklin Academy, Malone
Palmer, F. D., Jamestown High School
Palmer, Lelia B., Utica Free Academy
Pattee, Ernest N., Syracuse University
Peabody, James E., Morris High School, New York
Peckham, W. C., Adelphi College, Brooklyn
Perine, Eunice, State Normal College, Albany
Platzer, William H., Poughkeepsie High School
Porter, Eva M., Herkimer High School
Porter, R. A., Syracuse University

Radcliffe, Lewis, Port Jervis High School
Record, *Mrs* Carrie L., State Normal School, Fredonia
Reed, F. W., Dobbs Ferry

Richardson, C. H., Syracuse University
Robertson, C. B., State Normal School, Cortland
Robinson, Emma C., 426 S. 1st av. Mt Vernon
Roe, E. D., Syracuse University
Rogers, C. G., Syracuse University

Sadler, Nettie M., 907 University av. Syracuse
Schmitz, H. J., State Normal School, Geneseo
Scott, Irving D., 215 Erie st. Syracuse
Share, William W., Adelphi College, Brooklyn
Shear, S. R., superintendent of schools, Kingston
Shearer, John S., Cornell University, Ithaca
Sheldon, C. S., State Normal School, Oswego
Sherwood, Alfred B., Poughkeepsie High School
Sieberg, W. H. J., Hotel Winthrop, 7th av. and 125th st. New York, School 43
Sisson, E. P., Colgate Academy, Hamilton
Smallwood, W. M., Syracuse University
Smith, Charles H., Hyde Park High School, Chicago, Ill.
Smith, Ernest R., Syracuse High School
Smith, Kendall P., Perry High School
Smith, Oren R., Windham High School, Willimantic, Ct.
Sohon, M. D., Morris High School, New York
Stannard, J. Ellis, Adelphi Academy, Brooklyn
Stetson, Orlando S., Syracuse University
Streater, Katherine T., Lafayette High School, Buffalo

Tanner, J. H., Cornell University, Ithaca
Tarr, Ralph S, Cornell University, Ithaca
Taylor, Joseph S., 2275 Loring pl., University Heights, New York, School 19
Taylor, J. F., Olean High School
Tether, C. H., State Normal School, Oswego
Thomas, M. Smith, Central High School, Buffalo
Tompkins, Elizabeth M., Poughkeepsie High School
Trant, Amelia E., Masten Park High School, Buffalo
Traxel, Emma J., 230 N. 5th st. Reading, Pa.
Tufts, F. L., Columbia University, New York
Turner, George M., Masten Park High School, Buffalo

Van Arsdale, May B., Teachers College, New York
Vickery, Stephen A., Gloversville High School
Viertel, Samuel, 15 Kosciusko st. Brooklyn
Voegelin, Carl O., High School, Newark, N. J.
von Nardroff, E. R., Erasmus Hall High School, Brooklyn

Wardwell, Mary L., Central High School, Buffalo
Watson, B. M., Syracuse High School
Weatherlow, J. K. (Miss), Education Department, Albany
Weed, Henry T., Manual Training High School, Brooklyn
Welch, Emily H., Packer Collegiate Institute, Brooklyn
Wetmore, Edward W., State Normal College, Albany
Whitney, E. R., Binghamton High School
Wilcox, C. C., Starkey Seminary, Eddytown
Wilder, Burt G., Cornell University, Ithaca
Wilder, George F., Erasmus Hall High School, Brooklyn
Williams, Mary E., Cortland High School
Williston, Arthur L., Pratt Institute, Brooklyn
Willock, James H., St Stephens College, Annandale
Winslow, E. J., Elmira Free Academy
Wood, Thomas D., Teachers College, New York
Woodhull, John F., Teachers College, New York
Woodworth, Philip B., Lewis Institute, 5808 Ohio st. Chicago, Ill.
Wright, Isaac M., Westfield High School

INDEX

Action, summary of, 8.
Algebra, 147, 162, 173.
Auditing committee, report, 8.

Bailey, Prof., quoted, 109.
Baker, A. L., cited, 173.
Barachois, bar and tickle, by J. M. Clarke, 123-31.
Bergen, Joseph Y., Plant Physiology in Secondary Schools, 100-9.
Betz, W., Recent Tendencies and Open Questions in the Teaching of Elementary Geometry, 170-75.
Bigelow, Maurice A., Established Principles of Nature Study, 109-11; cited, 16.
Biklé, C. E., What Equipment is needed for the Effective Teaching of High School Mathematics, 151-59.
Biological courses in the high school, content of, 18.
Biological sciences, teaching in high schools, by L. B. Gary, 111-16; in Syracuse High School, by G. T. Hargitt, 117-19.
Biological survey project, 9.
Biology, committee, 9.
Biology as method and as a science in secondary schools, by H. R. Linville, 30-38.
Boole, Mrs M. E., cited, 76.
Botany, *see* Biological sciences; Plant physiology.
Burnham, Dr, cited, 11, 12, 13.

Castle, cited, 152.
Chemistry, domestic, course in, 20.
Clark, J. P., quoted, 170.
Clark, O. D., death, 9.
Clarke, John M., Barachois, Bar and Tickle, 123-31.
Coastal lagoons, 123-31.
Committees, reports, 9.
Comstock, Mrs, quoted, 116.
Conklin, E. G., cited, 19.

Earth science, laboratory exercises in, report of committee referred to, 9. *See also* Physical geography.
Education, synthetic principle in, 15.
Emerson, R. W., quoted, 22.

Farnham, Amos W., Relation which School Gardens may bear to Industrial and Commercial Geography, 132-40.
Federation, committee continued, 9.
Field work and contour maps, inductive study of relief forms in, by W. H. Platzer, 42-46.
Field work in physical geography, by J. T. Martin, 39-42.

Gale, A. S., Place of the Theory of Transformations in Geometry, 47-52.
Gardens, *see* School gardens.
Gary, Lester B., Teaching of Biological Sciences in Some of the High Schools in New York State, 111-16.
Geometry, 146, 158, 162; place of the theory of transformations in, by A. S. Gale, 47-52; of secondary schools, introduction of modern notions, by C. J. Keyser, 52-61; elementary, recent tendencies and open questions in the teaching of, by W. Betz, 170-75.

Hall, G. Stanley, cited, 12, 13, 19.
Hargitt, George T., Biological Sciences in Syracuse High School, 117-19.
Hawkes, H. E., Secondary Mathematics from a College Standpoint, 145-51.
High school courses in science, are they adapted to the needs of adolescents, by H. A. Kelly, 10-22.
Hodge, Prof., quoted, 109.

Industrial Education, National Association for Promotion of, 98.

Jameson, J. M., More Interesting and Practical Mechanics for the High School, 23-29.

Kelly, Henry A., Are High School Courses in Science Adapted to the Needs of Adolescents, 10-22.
Keyser, C. J., Concerning the Introduction of Modern Notions into the Geometry of Secondary Schools, 52-61.
Klein, F., mentioned, 173.

Laboratory exercises, in earth science, report of committee referred to, 9. *See also* Biological sciences; Physical geography.
Lagoons, 123-31.
Lancaster, E. G., cited, 13.
Langevin, P., quoted, 91.
Liard, L., quoted, 85-86.
Linville, Henry R., Biology as Method and as a Science in Secondary Schools, 30-38.
Lippmann, G., quoted, 89.

McMahon, J., cited, 173.
Mann, C. R., New Movement for Reform of Physics Teaching in Germany, France and America, 75-99; American Federation of Teachers of the Mathematical and the Natural Sciences, 175-77.
Martin, Jennie T., Field Work in Physical Geography, 39-42.
Mathematics, secondary mathematics from a college standpoint, by H. E. Hawkes, 145-51; library for high schools and normal schools, 154-56; relation between high school and college mathematics, by H. E. Webb, 159-68; teacher of in secondary schools, preparation of, by D. E. Smith, 62-68; what equipment is needed for the effective teaching of high school mathematics, by C. E. Biklé, 151-59; American federation of teachers of the mathematical and the natural sciences, by C. R. Mann, 175-77.
Mechanics, more interesting and practical mechanics for the high school, by J. M. Jameson, 23-29.
Members of Association, list, 178-81.
Miller, G. A., quoted, 174.
Minerals, study in physical geography in the high schools, by C. H. Richardson, 120-23.
Moore, Prof., cited, 170, 171, 172, 175.
Morrey, William T., Reference Books and Physical Geography Teaching, 140-44.
Myers, G. W., cited, 152.

Natural science study, defined, 16.
Natural sciences, American federation of teachers in the mathematical and the natural sciences, by C. R. Mann, 175-77.
Nature study, defined, 16; established principles of, by M. A. Bigelow, 109-11; special purposes, 134. *See also* School gardens.
Necrology, 9.
Newcomb, Simon, quoted, 174.
Nipher, F. E., quoted, 173.

Officers, 3.

Perry, Prof., quoted, 171.
Physical geography, field work in, by J. T. Martin, 39-42; inductive study of relief forms in field work and contour maps, by W. H. Platzer, 42-46; study of minerals and rocks in the high school, by C. H. Richardson, 120-23; reference books and physical geography teaching, by W. T. Morrey, 140-44.
Physics, more interesting and practical mechanics for the high school, by J. M. Jameson, 23-29.
Physics teachers, new move among, committee, 9; Eastern Association of, 93; other associations, 93.
Physics teaching, new movement for reform of in Germany, France and America, by C. R. Mann, 75-99.

Physiology, joint committee on, 9. *See also* Biological sciences.
Plant physiology in secondary schools, by J. Y. Bergen, 100-9.
Platzer, William H., Value of the Inductive Study of Relief Forms in Field Work and Contour Maps, 42-46.
Poincaré, Henri, quoted, 86-89.
Poincaré, Lucien, quoted, 89-91, 92.

Relief forms in field work and contour maps, inductive study of, by W. H. Platzer, 42-46.
Richardson, C. H., Study of Minerals and Rocks in Physical Geography in the High School, 120-23.
Rocks, study in the high school, by C. H. Richardson, 120-23.

Saxelby, F. M., cited, 152.
School gardens, relation to industrial and commercial geography, by A. W. Farnham, 132-40.
Science, high school courses in, are they adapted to the needs of adolescents, by H. A. Kelly, 10-22; intermediate general course, 16.
Science teaching seen from the outside, by E. L. Thorndike, 69-74.
Sciences, special, sequence of, 17.
Section officers, 8.
Sessions, summary of, 4-7.
Smith, David Eugene, Preparation of Teacher of Mathematics in Secondary Schools, 62-68; cited, 152, 153.
Swift, Edgar James, cited, 14.
Synthetic principle in education, 15.

Teacher of mathematics in secondary schools, preparation of, by D. E. Smith, 62-68.
Teachers College, vote of thanks to, 9.
Thorndike, Edward L., Science Teaching Seen from the Outside, 69-74; quoted, 152.

Webb, H. E., Relation between High School and College Mathematics, 159-68.
Whitman, E. C., cited, 20.

Young, Prof., mentioned, 175.

Zoology, *see* Biological sciences.

N. Y. State Library

Education Department Bulletin

Published fortnightly by the University of the State of New York

Entered as second-class matter June 24, 1908, at the Post Office at Albany, N. Y., under the act of July 16, 1894

No. 431 ALBANY, N. Y. September 15, 1908

PROCEEDINGS OF THE
12th ANNUAL MEETING
OF THE
NEW YORK STATE SCIENCE TEACHERS ASSOCIATION

Held at Cornell University, Ithaca, N. Y., December 27-28, 1907

PAGE

Officers 1907 3
Executive council 3
Committees 4
Summary of sessions 5
Summary of action 9
Section meetings
Section A—Physics and chemistry
  Measurement of Temperatures: J. S. Shearer 11
  Laboratories of Rockefeller Hall: Ernest Blaker 13
  Teaching of Elementary Electricity: R. C. Gibbs 16
  Wave Motion and Methods of Projection: C. W. Waggoner & E. C. Crittenden 18
Section B—Biology
  Teaching of Biology: H. H. Whetzel 21
  Aim and Method in Secondary Biology: M. F. Goddard 24
  By-products of Biology Teaching: B. C. Gruenberg 33
Section C—Earth science
  Use of a Wet Laboratory in Physiography Teaching: O. D. von Engeln 44
  Laboratory Work in Physiography: M. G. Sullivan 50

PAGE

Section B—Biology
  Work of a Children's Museum: A. B. Gallup 54
Section C—Earth science
  Street Car Excursion to Points of Physiographic Features of the Ithaca Region: Led by O. D. von Engeln 62
  Electrical Oscillations: J. S. Shearer 63
Section A—Physics and chemistry
  Study of Science by Young People: W. S. Franklin 65
Section B—Biology
  Educational Uses of Sharks and Rays: B. G. Wilder 95
  First Year Biology in New York City: Zillah Heidenheim 97
  Experimental Work in Biology: C. A. King 102
Section C—Earth science
  Power Questions and their Value: J. T. Martin 107
  Purification of Water: E. M. Chamot 109
  Teaching of Science: L. H. Bailey 110
Members 1908 116
Index 121

ALBANY
UNIVERSITY OF THE STATE OF NEW YORK
1908

[illegible]

STATE OF NEW YORK

EDUCATION DEPARTMENT

Regents of the University

With years when terms expire

1913	Whitelaw Reid M.A. LL.D. D.C.L. *Chancellor*	New York
1917	St Clair McKelway M.A. LL.D. *Vice Chancellor*	Brooklyn
1919	Daniel Beach Ph.D. LL.D.	Watkins
1914	Pliny T. Sexton LL.B. LL.D.	Palmyra
1912	T. Guilford Smith M.A. C.E. LL.D.	Buffalo
1918	William Nottingham M.A. Ph.D. LL.D.	Syracuse
1910	Charles A. Gardiner Ph.D. L.H.D. LL.D. D.C.L.	New York
1915	Albert Vander Veer M.D. M.A. Ph.D. LL.D.	Albany
1911	Edward Lauterbach M.A. LL.D.	New York
1909	Eugene A. Philbin LL.B. LL.D.	New York
1916	Lucian L. Shedden LL.B. LL.D.	Plattsburg

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Assistant Commissioners

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Director of Science and State Museum

John M. Clarke Ph.D. LL.D.

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Educational Extension, William R. Eastman M.A. M.L.S.
Examinations, Charles F. Wheelock B.S. LL.D.
Inspections, Frank H. Wood M.A.
Law ———
School Libraries, Charles E. Fitch L.H.D.
Statistics, Hiram C. Case
Trades Schools, Arthur D. Dean B.S.
Visual Instruction, DeLancey M. Ellis

Education Department Bulletin

Published fortnightly by the University of the State of New York

Entered as second-class matter March 3, 1908, at the Post Office at Albany, N. Y., under the act of Congress of July 16, 1894

NO. 431 ALBANY, N. Y. SEPTEMBER 15, 1908

PROCEEDINGS OF THE
12th ANNUAL MEETING
OF THE
NEW YORK STATE SCIENCE TEACHERS ASSOCIATION

Held at Cornell University, Ithaca, N. Y., December 27-28, 1907

OFFICERS 1907

President, J. S. Shearer, Cornell University, Ithaca
Vice President, E. D. Roe, Syracuse University
Secretary-Treasurer, J. E. Stannard, Adelphi Academy, Brooklyn

EXECUTIVE COUNCIL

Terms expire 1910

G. M. Turner, Masten Park High School, Buffalo
T. C. Hopkins, Syracuse University
Charles Newell Cobb, State Education Department, Albany

Terms expire 1909

A. P. Brigham, Colgate University, Hamilton
C. E. Harris, East High School, Rochester
Howard Lyon, Oneonta Normal School

Terms expire 1908

L. V. Case, Washington Irving High School, Tarrytown
W. T. Morrey, Morris High School, New York city
J. S. Shearer, Cornell University, Ithaca

Terms expire 1907

A. W. Farnham, Oswego Normal School
F. L. Bryant, Erasmus Hall High School, Brooklyn
J. E. Kirkwood, Syracuse University

COMMITTEES

Committee on federation

JOHN F. WOODHULL, Teachers College, New York city, *Chairman*
GEORGE M. TURNER, Masten Park High School, Buffalo
HOWARD LYON, Oneonta Normal School

Committee on new move among physics teachers

Under charge of section A

JOHN F. WOODHULL, Teachers College, New York city, *Chairman*
J. S. SHEARER, Cornell University, Ithaca
O. C. KENYON, Syracuse High School
E. S. WETMORE, State Normal College, Albany
L. E. JENKS, Ogdensburg High School

Committee on biology in secondary schools

J. E. PEABODY, Morris High School, New York city, *Chairman*
W. M. SMALLWOOD, Syracuse University
GEORGE F. ATKINSON, Cornell University

Committee to aid in the biological survey project

CHARLES W. DODGE, University of Rochester, *Chairman*
C. W. HARGITT, Syracuse University
C. W. HAHN, High School of Commerce, New York city

Local committee on arrangements

J. S. SHEARER, *Chairman;* R. S. TARR, L. M. DENNIS, H. REIS, E. BLAKER, B. F. KINGSBURY, H. D. REED, E. J. DURAND, C. H. TUCK, A. E. WELLS

SUMMARY OF SESSIONS

FRIDAY MORNING, DECEMBER 27

Council meeting. Room 130, Rockefeller Hall

General meeting. Lecture room A, Rockefeller Hall

Address of welcome, President Schurman

Introduction of *President-elect* Shearer by retiring *President* Woodhull

Section meetings

Section A — Physics and chemistry. Room B, Rockefeller Hall

1 The Measurement of Very High and of Very Low Temperatures
J. S. Shearer, Cornell University

2 Inspection of Laboratories of Rockefeller Hall, to see various laboratory experiments asked for by teachers
Under direction of Ernest Blaker, Cornell University

3 Some Suggestions Regarding the Teaching of Elementary Electricity
R. C. Gibbs, Cornell University

4 Some Experiments Illustrating Wave Motion and Methods of Projection
C. W. Waggoner and E. C. Crittenden, Cornell University

Section B — Biology. Amphitheater, Stimson Hall. Esther F. Byrnes, Girls High School, Brooklyn, *Chairman*

1 Factors that Make for Success in the Teaching of Biology in our High Schools
H. H. Whetzel, Cornell University

2 Aim and Method in Secondary Biology
Martha F. Goddard, Morris High School, New York city

3 Some By-Products of Biology Teaching
Benjamin C. Gruenberg, DeWitt Clinton High School, New York city

4 Discussion of questions sent, for the question box

5 Communications read by the secretary

Section C — Earth science. Geological lecture room, McGraw Hall. Jennie T. Martin, Business High School, Washington, D. C., *Chairman*

1 The Use of a Wet Laboratory in Physiography Teaching; illustrated by lantern slides

OSCAR D. VON ENGELN, Cornell University

2 Discussion: Laboratory Work in Physiography, its Advantages and Dangers

MARY GERTRUDE SULLIVAN, Masten Park High School, Buffalo, N. Y.

FRIDAY AFTERNOON, DECEMBER 27

Luncheon in Sage College

Section A — Physics and Chemistry. Chemical laboratory lecture room, Morse Hall

1 Demonstrations

Given by L. M. DENNIS

a Some Illustrative Experiments in Elementary General Chemistry

b The Electric Furnace and Some of its Products

c Preparation of Molten Iron for Welding by Use of Thermite

2 Inspection of the Chemical Laboratories

Under direction of L. M. DENNIS, Cornell University

Section B — Biology. Botanical lecture room, Sage College.

ESTHER F. BYRNES, Girls High School, Brooklyn, *Chairman*

1 The Work of a Children's Museum, illustrated by stereopticon slides

ANNA BILLINGS GALLUP, Brooklyn Institute of Arts and Sciences

2 Inspection of Apparatus used in the Department of Botany

Conducted by DR E. J. DURAND, Cornell University

Section C — Earth science. Geological lecture room, McGraw Hall. JENNIE T. MARTIN, Business High School, Washington, D. C., *Chairman*

Examination of physiographic and geologic laboratories of Cornell University

Street car excursion: Physiographic Features of the Ithaca Region

Led by OSCAR D. VON ENGELN, Cornell University

FRIDAY EVENING, DECEMBER 27

General meeting. Lecture room A, Rockefeller Hall

1 The Development of Atomic Theories

L. M. DENNIS, Cornell University

2 Electrical Oscillations
J. S. SHEARER, Cornell University

Several experiments in connection with these two informal talks were kept in operation after the session for comment and questions.

Reception by President and Mrs Schurman at the President's House, 41 East Avenue, Campus

SATURDAY MORNING, DECEMBER 28

Section meetings

Election of section officers and miscellaneous business

Section A — Physics and chemistry

1 Exhibition of Liquid Air Plant in Operation
F. K. RICHTMYER, Cornell University
2 Inspection of Dynamo Laboratory
F. BEDELL, Cornell University
3 Photography Laboratory
G. S. MOLER, Cornell University
4 Exhibit of Lantern Slides prepared by the Lumière Color Photography Process
DR E. R. VON NARDROFF, Erasmus Hall High School, Brooklyn
5 Talk on Wireless Telephony
C. D. CHILDS, Colgate University, Hamilton, N. Y.
6 The Study of Science by Young People
WILLIAM S. FRANKLIN, Lehigh University, South Bethlehem, Pa.

Section B — Biology. Room 5, McGraw Hall. ESTHER F. BYRNES, Girls High School, Brooklyn, *Chairman*

1 The Educational Uses of Sharks and Rays, especially the Acanth (Squalus Acanthias, " horned dogfish ")
BURT G. WILDER, Cornell University
2 First Year Biology in New York City
ZILLAH HEIDENHEIM, Curtis High School, Staten Island
3 Experimental Work in Biology
CYRUS A. KING, Erasmus Hall High School, Brooklyn
4 Inspection of Department of Vertebrate Zoology, Cornell University

Section C — Earth science. Geological lecture room, McGraw Hall. JENNIE T. MARTIN, Business High School, Washington, D. C., *Chairman*

1 How to make relief models of small areas, with an explanation of a peculiar and interesting glacial valley
T. C. Hopkins, Syracuse University
2 Power Questions and their Value
Jennie T. Martin, Business High School, Washington, D. C.
3 Brief contributions from members, including new laboratory exercises, teaching devices, results of field investigations, etc.

Council meeting. Room 130, Rockefeller Hall
General meeting. Room A, Rockefeller Hall

1 Report of treasurer
2 Report of auditing committee
3 Report of nominating committee, election of officers, announcement of place of next meeting
4 Necrology
5 Reports of standing committees and delegates
6 Miscellaneous business
Address: The Outlook of Science Teaching
L. H. Bailey, Cornell University

SATURDAY AFTERNOON, DECEMBER 28

Luncheon, Sage College

General meeting. Room 2, Morse Hall

The Purification of Water
E. M. Chamot, Cornell University

Followed by a visit to the Carnegie filtration plant on the Campus. Other points of interest visited were the shops and laboratories of Sibley College and of the College of Civil Engineering, the power plant in the gorge, an example of small flow, high pressure hydraulic system, the Medical College, etc.

SUMMARY OF ACTION

Treasurer's report

Summary as per books and vouchers on file for year ending December 28, 1907

Receipts

Dec. 27, 1906	Balance on hand	$148 09
Dec. 28, 1907	Dues to date	101 ..
	Total	$249 09

Expenditures

Dec. 28, 1907	Total to date	$101 35
Dec. 28, 1907	Balance on hand	147 74
		$249 09

Auditing committee. The auditing committee has examined the report of the treasurer of the New York State Science Teachers Association and finds it to be correct.

O. C. KENYON } *Committee*
I. P. BISHOP }

December 28, 1907
Report accepted

Nominating committee. The nominating committee made the following nominations: *President,* O. C. KENYON, Syracuse High School; *vice president,* W. M. SMALLWOOD, Syracuse University; *secretary-treasurer,* E. R. SMITH, Syracuse High School

For members of the council (term to expire 1911)

E. R. VON NARDROFF, Erasmus Hall High School, Brooklyn

C. B. ROBERTSON, Cortland Normal School

M. A. BIGELOW, Teachers College, New York

Motion was made and carried that the secretary cast the unanimous ballot of the association for those nominated.

Place of meeting

Syracuse was named as the next place of meeting.

Necrology

R. J. KITTREDGE, Erie, Pa. died November 1907.

Report of committees

The committee on Biological Survey reported progress and was continued.

No reports from other committees. Their work is to extend through a number of years so all committees were continued.

J. E. Peabody, Morris High School, New York, was released (upon request) from the chairmanship of the committee on biology. W. M. Smallwood, Syracuse University, was made chairman and Miss Esther Byrnes of Girls High School, Brooklyn, was added to the committee.

Section officers for 1908

Section A — Physics and chemistry

Chairman and secretary to be chosen by the new president

Section B — Biology

Chairman, L. S. HAWKINS, Cortland Normal School

Section C — Earth science

Chairman and secretary to be chosen by the new president

Vote of thanks. A vote of thanks was extended to Cornell University for its hospitality.

SECTION MEETINGS

Friday morning, December 27

Section A — PHYSICS AND CHEMISTRY

THE MEASUREMENT OF VERY HIGH AND OF VERY LOW TEMPERATURES

BY J. S. SHEARER, CORNELL UNIVERSITY

All comparisons of temperatures depend finally on the recurrence of some convenient physical state of phenomena which depends on thermal condition. Experience shows that the volume of a fixed amount of liquid returns to the same value when, after changes in temperature, it is again brought to its initial condition as regards temperature.

While change of volume of liquids or the change of pressure and volume of a gas are the physical properties more commonly used for temperature comparisons they are by no means the only ones now in practical use for this purpose. We may use any physical property which varies with temperature in order to make such measurements. Among the most convenient may be mentioned the following: change in electrical resistance, thermal electro-motive force, production of luminous radiation, thermal radiation, etc. None of these may be applied at all temperatures and their respective limitations may be briefly noted.

Liquid thermometers are limited by the melting and boiling points of the liquid used. Alcohol, for example, boils at a comparatively low temperature and freezes only in extreme cold, yet it becomes viscous long before solidification and is therefore not very useful as a thermometric fluid. Mercury freezes at about 40°C. and by increasing the pressure to which it is subjected and using quartz instead of glass tubes temperatures of 700°C. may be indicated. For extreme low temperatures petroleum ether may be used down to 190°C. for approximate measurement.

The gas thermometer while inconvenient in use has a range from the lowest temperature yet attained to about 1100°C., the upper limit being determined by our inability to secure suitable containers for the gas. It is also the final standard for temperature measurements and is used in the standardization of all accurate thermometers.

The electric resistance thermometer may be used from about 200° to 1000°C. The relation between change of temperature and change in resistance is decidedly modified below 200°, and even metals which do not melt at, or below, 1000°C. begin to evaporate at that point and are not reliable because of decrease of cross-section.

The thermojunction has a range from about the lowest known to about 1500°C. by using very refractory metals like platinum and some of its alloys.

No thermometer yet devised of the types mentioned exceeds the range of the thermocouple and yet much higher temperatures must be measured daily in the control of modern manufacturing processes. To meet these needs there have been developed several types of pyrometers as they are called which give fairly consistent results for temperatures between about 700° and 3600°, i. e. from a dull red heat to the temperature of the electric arc. These instruments all depend on the laws of radiation, which are applied in various ways to accomplish the result.

The simplest is the Morse thermogage which may be illustrated by heating a wire by an electric current and holding it just in front of a red hot plate of metal. If the wire is cooler than the plate it will appear as a dark line on a bright background while if hotter the reverse will be the case. When the wire is practically invisible its temperature is very close to that of the plate. By using an incandescent lamp instead of the wire and a suitable optical arrangement this becomes a practical instrument of certain ranges especially those used in the manufacture of steel.

The Féry pyrometer may be illustrated by using a hot metal ball, a concave mirror and a thermopile. When the image of the ball is formed on the pile an indication is given which is in proportion to the temperature of the ball. Other instruments use the light from the hot body as compared with that from a standard source.

The radiation pyrometer has the great advantage of avoiding contact with the hot body and as no part is ever heated to any high temperature they are not likely to be damaged. One point should be kept in mind, however, that the radiation from a body does not depend exclusively on its temperature but also on the nature of its surface, so that calibrations are made in terms of an ideal arrangement termed a " black body " and the deviation from this is to be determined in any particular case.

INSPECTION OF LABORATORIES OF ROCKEFELLER HALL

UNDER DIRECTION OF ERNEST BLAKER

During the Ithaca meeting of the New York State Science Teachers Association December 27 and 28, 1907, the practice laboratories of the department of physics were open at any time for inspection by those interested. Eight members of the instructing staff were present to act as guides and to show such apparatus and experiments as were asked for in communications sent in to the president of the association.

Some experiments in wave motion, sound and lantern projection were shown in the section meetings which are outlined elsewhere. In the practice laboratories experiments were shown supplementing those just mentioned. In wave motion a heavy, soft copper spiral loosely coiled and suspended with its axis horizontal by long strings fastened to a horizontal support and the individual turns, was used to show longitudinal compressional waves and stationary waves. Melde's experiment was operated with two strings whose tension was regulated to give vibrating segments of equal length, one string being stretched parallel to the axis of the fork and the other perpendicular to the axis both being in the plane of the prongs. Kundt's experiment was demonstrated using an improved form of apparatus with powdered quartz in the tube. The ordinary forms of sonometers were also shown.

A 12 foot concave Rowland reflection diffraction grating was used to show the spectrum produced by a Cooper-Hewitt mercury lamp. Diffraction spectra were also produced by means of transmission gratings. The prismatic spark spectrum of lead was shown using a heavy flint glass prism. Interference bands produced by the Michelson interferometer using sodium light and the rotation of the plant of polarization in a magnetic field completed the regular exhibit in light.

In heat, apparatus was shown for finding Joules equivalent by the electrical and mechanical method, for comparing thermometers and measuring temperatures by means of the platinun resistance thermometer, and for finding specific heats by Joly's steam calorimeter.

In electricity and magnetism a few of the pieces of apparatus and experiments shown are noted below: Magnetometers, quadrant electrometer, sensitive and nonsensitive tangent and d'Arsonval galvanometers for current, quantity and potential measurements, portable d'Arsonvals used for zero methods; different types of wheatstone bridges, the Carey-Foster bridge, and three styles of slidewire bridges.

A device for producing an alternating E. M. F. of high frequency but low voltage for use in measuring the resistance of electrolytes was in operation. The heating effect and consequent change of resistance of the electrolyte is practically eliminated by using this apparatus. The same apparatus was also used in the experiment on comparing the capacity of condensers by the bridge method. The pitch of the tone emitted may be regulated to suit the experimenter within quite wide limits.

Two small motor generator sets were in operation. One was made up of a ½ hp. direct current motor directly connected to a two phase generator which in turn was used to drive a squirrel cage induction armature. The effect of the rotating field in this case was also shown by using light weight conductors in it which were easily rotated. The other motor generator set was made up of a ½ hp. single phase inductor motor driving by means of a belt a 20 volt direct current generator which was used to supply current for various experiments including electrolysis.

The general photomotry laboratory is connected with the practice laboratories and in this division various photometers and light sources were exhibited.

In addition to the general exhibit outlined above, one morning was devoted to special demonstrations. The liquid air plant, the joint property of the departments of chemistry and physics, was operated under the direction of Mr F. K. Richtmyer who explained the operation in detail. Mr Richtmyer discussed the properties of liquid air, its composition as it aged and outlined its effects on the properties of various substances, and its usefulness in scientific research.

Following the liquid air demonstration Frederick Bedell assisted by C. A. Pierce conducted the visitors through the dynamo and alternating current laboratories of the department of physics where many interesting direct and alternating current phenomena were shown. These laboratories are used especially for research work and the general instruction of students in science.

In the department of physics there has been developed by G. S. Moler a photographic laboratory where instruction is given in the ordinary photographic processes but it is more especially designed to prepare students for the use of photography in scientific work. This laboratory, which was the last visited, occupied the whole of the third floor in the north wing and a suite of rooms in the central section of the building. Mr Moler conducted the guests through this laboratory and explained the arrangement of rooms and the facilities of his department.

SOME SUGGESTIONS REGARDING THE TEACHING OF ELEMENTARY ELECTRICITY

BY R. C. GIBBS, CORNELL UNIVERSITY

The method of presenting the subject of electricity will depend to a large extent upon what topics in physics have been previously studied. Let us suppose then the student has a fairly good knowledge of the principles of elementary mechanics, heat and magnetism. In magnetism let us assume that he knows the magnetic effects of current and the elementary laws connected therewith.

Granting this preparation we may at once begin the study of the laws of electric charges, first considering them as static and secondly as moving charges i. e. current electricity. The crucial point of the whole subject lies in getting the student to see the identity of the two kinds of electricity. He must be brought to realize that if a charge of electricity developed by whatever means, whether frictional, chemical, thermal, or inductional (e. g. as in a dynamo) is connected by a conductor to a place of lower potential, a current will result.

Experiments which demonstrate this identity include, among others, the testing for fall of potential through a resistance of several incandescent lamps in series in a 500 volt circuit, by means of an electroscope; the indication of current by means of a galvanometer when a condenser is charged from an electrostatic machine; the indication of current by means of a sensitive galvanometer when the armatures of a charged condenser placed on an insulated support are alternately discharged through the body. Other experiments depending upon the magnetic effects of current may be used to establish still further this identity.

In fixing in the mind of the student the relations between electric quantities much may be gained by comparing them step by step with the analogous phenomena which occur in a system of water pipes. Resistance, potential, capacity and several other terms all have their water analogue. Of course the analogy is not complete in several details, e. g. in the water system there is nothing corresponding to the magnetic field which surrounds a conductor carrying a current. The question of the capacity of a condenser, so often troublesome because of the common meaning attached to the term, may be quite accurately illustrated by considering the amount of air which can be forced into an elastic bag in order to produce a certain pressure.

Although the electric current might be measured more or less accurately by any one of its effects, viz, magnetic, chemical, thermal, or physiological, yet the first affords the most direct method of procedure because of the simple proportionality between the intensity of magnetic effects and that of current. This effect is independent of the size and nature of the conductors.

Among the quantities to be measured or computed in connection with electricity, that of the amount of work done, or energy consumed in any part of a circuit is generally troublesome. This is often due to the failure on the part of the student to understand or on the part of the teacher to present correctly the fundamental notion of potential. As soon as the student thoroughly grasps the idea that potential is something which will cause electric charge to move from one point of a conductor to another when for any reason the potential or pressure at the second point is less than that of the first, he has gone a long way toward clearing up what would otherwise be a more or less hazy conception of the whole subject of energy relations. Remembering that potential difference between two points is measured by the amount of work done in carrying unit charge from one point to the other, it is not difficult to see that if more charge were carried between the same points or the same charge between two points having a greater difference of potential a proportionally greater amount of work would be done.

Without going into detail it may be sufficient to call attention to the fact that the solution of Ohm's Law problems by mere substitution in a formula is worse than useless. An understanding of the principles underlying the formula referred to, together with a knowledge of its limitations, is essential.

Another topic which should receive considerable attention in the study of electricity is that of induced E. M. F. There are several other minor topics which should not be entirely omitted such as, electrolysis, passage of electricity through gases, and high frequency oscillations. The main object of this paper, however, has been to emphasize the importance of teaching the identity of electrostatic and current electricity, to suggest the expediency of using some analogy which will appeal to everyday experience, to point out the necessity of paying special attention to the fundamental notion of potential, and to discourage the mechanical method of solving problems by mere substitution in formulae of whose meaning and limitations the student has little or no idea and of which practice the Ohm's Law problems are glaring examples.

SOME EXPERIMENTS ILLUSTRATING WAVE MOTION AND METHODS OF PROJECTION

BY C. W. WAGGONER & E. C. CRITTENDEN, CORNELL UNIVERSITY

In response to requests for experiments in wave motion a few pieces of homemade apparatus were exhibited. Transmission of waves at a speed slow enough for convenient observation is shown by a piece of steel tape loaded with transverse sticks at intervals of a few inches and hung by one end from a suitable support. The lower end is left hanging free, so that reflection is shown with change of phase at the upper (fixed) end and without change of phase at the lower end. This device can be used also to show the passage of wave trains through one another. Additional weighting of a part of the tape makes it a "denser medium," for example by binding additional sticks upon those of the upper end we get partial reflection and partial transmission of the waves.

Standing waves can be readily shown in several ways. Good effects are obtained with a cord, one end of which is whirled by an eccentric cam on a small motor, while the other end is passed over a pulley and held by suspended weights. This affords a means of regulating the tension; the frequency can be readily altered by control of the motor; the effect of variation in mass of the string can be shown by using a light and a heavy cord in series. Polarization of the waves along the cord can be produced by a slip placed at an antinode, and a second slit furnishes an excellent analogy for the analyzer. Two details in the design exhibition of this apparatus are perhaps worth mentioning: first, the eccentric cam should have a swivel joint with a harness to prevent twisting of the cord; second, the cord can be made clearly visible by darkening the room and setting a lantern so as to throw a beam of light along the cord.

Another piece of apparatus can be made out of a section of galvanized iron conductor pipe 3 or 4 inches in diameter and 10 to 15 feet long. Close the ends, one by a sliding plug and the other by a piece of stretched rubber dam. Provide an inlet for coal gas, and along one side of the pipe drill a series of small holes all of the same size at intervals of about an inch. The gas jets thus made are lighted, giving a uniform row of flames. If then a continuous and fairly intense sound is produced near the rubber membrane and the sliding plug is adjusted so as to tune the pipe to this sound, the nodes and antinodes in the pipe will be distinctly shown by the variation in hight and color of the flames. The gas pressure in the pipe must be rather small.

Beautiful systems of standing waves are easily produced on the surface of mercury. A steady system can be obtained by running a motor on the table or by putting into the mercury one end of a wire which is connected to an electrically driven tuning fork. Instructive variations are made by using vessels of various shapes, such as circular, elliptical, or triangular. Two vibrating wires as sources produce systems of waves in which the lines of destructive interference are plainly marked. In the case of the elliptical vessel, if a vibrating wire is put near one focus the second focus is shown by the wave arrangement. The mercury surface is a good reflector, and by using two plane mirrors and a focusing lens the light from a lantern can be made to give a very good image of the surface on a screen. For this purpose it is well to remove the focusing lens of the lantern and one of the condensers in order to get approximately parallel rays thrown upon the mercury surface.

A spectroscope assembled out of ordinary lecture room equipment was used to show several bright line spectra and also the reversal of the sodium lines giving the corresponding dark lines in the spectrum. The "spectroscope" used is the usual arrangement of lantern, focusing lens, and prism to give a spectrum. The lantern, however, must be hand fed; the various salts and metals are then introduced directly into the arc, their lines appearing superposed on the continuous spectrum of the arc. Occasionally when the lantern becomes filled with comparatively cool vapor, reversal of lines will be obtained. To get this reversal at will put in the path of the beam of light, at its narrowest part, a joint of stovepipe with two slits at opposite sides to allow passage of the light. In the pipe with a blast lamp vaporize a quantity of metallic sodium. The vapor absorbs the wave length in the yellow characteristic of sodium, and black lines appear in their place in the spectrum.

As further examples of spectroscopic apparatus some diffraction gratings of each type, that is, transmitting and reflecting, were shown, some with simple mounting used in laboratory instruction, others with the more elaborate machinery used in research work.

Attention is especially invited to the fact that a large part of the equipment shown is homemade, and that much of it can be duplicated in any shop. No teacher of physics need despair because he lacks finely finished and expensive apparatus. Fortunately we find that the more simple the apparatus is, the more readily does the student grasp the underlying principle, and what we want is not a knowledge of the equipment in any particular laboratory but a comprehension of the fundamentals on which all physical operations depend.

Section B — BIOLOGY

FACTORS THAT MAKE FOR SUCCESS IN THE TEACHING OF BIOLOGY IN OUR HIGH SCHOOLS

BY H. H. WHETZEL, CORNELL UNIVERSITY

When in reply to the kind invitation of your chairman to speak to you on this occasion, I replied that I would attempt to outline what appeared to me to be the factors that made for success in the teaching of biology in our high schools, I felt that it would be an easy matter for me to concrete and classify my ideas on the subject. The task has proven to be not without difficulties. While the four characters or characteristics that I shall briefly discuss are not to be considered the only ones that figure in successful biology teaching, yet they appear to me to be among those of first importance.

Since our ideas and opinions on such a subject are very largely determined by our experiences, I have kept before my mind in the preparation of this paper a few good teachers of biology that I have been so fortunate as to know well Not all of them are high school teachers. Yet I feel sure that those of them that teach in college or university would be equally successful if teaching in high schools. We should remember that the college freshman is only a high school senior three months later.

With possibly that one exception that proves the rule, I find that every one of these teachers is thoroughly and broadly trained in the subject-matter of biology. They know the subject-matter. They are able to view the whole field and distinguish the great factors in life phenomena. They have clear conceptions of the structure, physiology and evolution of living things. They appreciate keenly the interrelations of plants and animals. They bristle with suggestions of related things. They see the plant not merely as a composite of root, stem, leaf and flower, a thing to be analyzed and named, to be pressed and mounted on a herbarium sheet, but a vitally living organism, thrusting its roots into the soil, seeking and absorbing food and water therefrom, spreading its broad green leaves to the sun and air, that carbon may be gathered for the manufacture of starch and sugar, elaborated foods for the use of the living protoplasm of each active cell, unfolding its rich red blossoms to the insect world that pollination may be effected, fertilization accomplished and its posterity assured. To know plants and animals in relation to their environment, and to each other, to see them meet and solve the problems of their existence and perpetuation, to understand something of the history of their evolution, this is to know the subject-matter of biology.

I recall also that all these teachers (and here there is no exception), are enthusiastic. They glow with enthusiasm born of knowledge and it is abiding and contagious. Enthusiasm on the part of the teacher begets interest on the part of the student. The teacher for whom every living thing has a message, to whom every living thing presents problems to be solved, can not fail to arouse interest and enthusiasm in pupils. As my own biology teacher used to say, such teachers have the "divine touch." Of none could this be more truly said than of him. A half hour's talk with him would fire me with enthusiasm and energy for weeks of hard work. It does still when I have the good fortune to be with him for a visit. To his inspiration more than to anything else do I attribute my interest and ambition along biological lines. The man who lacks enthusiasm, be he ever so wise, can not teach. His enthusiasm must be broad, it must not be special. The whole field, all the problems must be vital to the teacher of biology. Therefore his enthusiasm must be readily and quickly transferred. The problem in hand today, the plant just found, the animal just captured, must be the thing of vital importance and interest and it must present problems and possibilities.

Another common characteristic of these teachers is that they are hard workers. Every teacher knows that the lesson that receives the most preparation and study by the teacher is the best taught. The interest and enthusiasm of the pupil are directly proportional to the amount of work put upon the subject by the teacher. If you don't believe this try it. I well remember the amazement with which I learned that my biology teacher spent three hours in the preparation of every lecture that he gave us, though he had taught the subject for at least ten years. My amazement continues to this day but it is now that he should have been able to have given such wonderful lectures with so little preparation. Hard work on the part of the teacher is, if properly directed, sure to result in hard work and interest on the part of the pupil. The lazy teacher should never expect pupils to work.

These teachers of mine are all keen observers. They see the great problems of living things in the plants and animals around them. The waste of weeds beside the path, the stagnant pond, the miry marsh or thorny thicket teem with life and so with interest. What a revelation and inspiration was my first field trip with a teacher who could really see things! I had gone over the same grounds many times before but I had never before seen half the things we found that day. I have since learned that much of the secret of finding living things is in knowing what you are looking for, but more in knowing the related environment, in other words in knowing the organism where it lives, in knowing it at home. But not only must the teacher be keenly observant himself, he must be able to open the eyes of his pupils. Information and inspiration are the clay and spittle of that miracle.

And finally the ability to teach common things seems to me to be a characteristic of all these teachers that I have in mind. They at once related me to my environment. A jar of pond water from a near-by creek brought the first message of cell life, its structure, its physiology, its evolution. Pith from the elder bush I had known all my life, a potato from the patch I had so often hoed, a twig from the basswood tree by the laboratory door, gave me my first insight into the wonders of cell structures, tissues, their specializations and adaptations, division of labor and development of plant organs, etc. Life with all its problems of origin and evolution was at my door. I had only to reach out and take and touch and handle it, examine and delve into its mysteries. The problems were mine for the asking, their solution mine for the trying. For only finding out is fun and only work is living.

AIM AND METHOD IN SECONDARY BIOLOGY

BY MARTHA F. GODDARD, MORRIS HIGH SCHOOL, NEW YORK CITY

What does secondary biology amount to? We hear this question asked again and again. Sometimes it comes in a parent's letter to a newspaper, denouncing the teacher who asked his little daughter to discover how many times a locust breathes in a minute. Sometimes a discouraged young teacher, fresh from college, asks the question, when she finds that the facts she has been cramming into her pupils' reluctant brains are returned to her, if at all, in a hardly recognizable condition. Many college professors tell us frankly that most high school biology courses amount to nothing.

To the parent, we say, "Wait until the year is over before you judge." The young teacher and college professor are in no position to understand the limitations of the immature minds we are teaching, and she, in her lessons, and he, in his entrance examination, have demanded the impossible.

When the question is asked, however, by our own principals, who have been studying these children for years, it is another matter. We acknowledge that biology does not yet mean as much as we hope it will in years to come, but we fully believe that if secondary biology is not amounting to more for our pupils than any other single subject, the trouble is not with biology.

If teachers without training, or with heavy programs including a variety of subjects, are obliged to undertake the work, the measure of success will be limited. Again, the fault may lie with the teacher, for one thing is certain: no class in biology will get much out of a course, if their teacher has not put much of himself into it. "Research work is my joy. I teach to earn my bread and butter," is an unpardonable position for a high school teacher to take. If any of us are guilty of that, our principals may be expected to notice lack of enthusiasm in our pupils.

The pioneer character of our work is chiefly responsible for the results of which certain principals complain. Fifteen years ago, biology had but a small place on our high school curriculum. In spite of what science is doing for us as a nation, we were far behind some European countries in the feeling that every one should understand the rudiments of science. A glance at the accompanying table, showing the amount of science required in classical courses in one of the best Swiss and one of the best American schools in 1897, will show the relative prominence 10 years ago. In many schools the same contrast still remains.

Required science

GYMNASIUM, AARAU, SWITZERLAND | CLASSICAL HIGH SCHOOL, WORCESTER, MASS.

	1st yr		2d yr		3d yr		4th yr		Total av. per week for 1 year		1st yr	2d yr	3d yr	4th yr
Botany	3	2							2½					
Zoology			2	2					2					
Anthropology					2	1			1½	½	½			
Mineralogy														
Geology							2	1	1½					
Physics			2	2	2	2	2	2	6					[a]5
Chemistry					2	2	2	2	4					
Total of science									17½					
Total of required work									119½	78½ or 83½				

[a] Without Greek.

We have been doing pioneer work and yet we have been expected to be as successful as teachers of Latin, Greek and mathematics.

Our first problem was to decide what we wanted our biology teaching to amount to — what we were aiming at.

To choose the right aim, we are obliged, in common with all teachers, to study our individual pupils and learn their limitations. As biology teachers, we must give especial attention to their environment, that we may select for study the "best things in nature" for them to learn, in order to make "their lives most worth the living," as Dr Hodge has so aptly described the aim in nature study.

We had to try experiments, and I must briefly review our attempts, for some schools are still following the first paths, which nearly all of us abandoned when most of the biology work was transferred to the pupils of the first year, even though we are still obliged to follow them a little more than seems wise, sometimes, in our elective courses.

To give instruction in the science of biology from the standpoint of evolution was the *first* aim. It was a logical course for ideal pupils, in which a series of typical plants or animals were dissected, drawn, labeled and discussed — if time permitted. Necessarily many entirely unfamiliar specimens preserved in alcohol or other evil smelling preservative, had to be studied. This dissection of preserved material Principal Russell of the Worcester Normal School has characterized as "canned biology." The logical, evolutionary order of presentation still prevails in our second or elective course in zoology or botany, but at the present time we have little "canned biology" even there. For our first year course, the definite attempt to teach evolution has been practically abandoned. Any one who attempts to condense such a course into one third of a year and to adapt it to pupils of fourteen is attempting the impossible.

A *second* aim, mental training in accuracy of observation and expression, has been and always must be one of the chief aims in biology, as in all study of science. The objects selected to give this training have changed from time to time.

At first, much microscopic study was required, if we were fortunate enough to possess microscopes. Our pupils drew our beautiful sections and perhaps lined them in with ink and carefully labeled them with technical terms. This required time and patience and gave a certain dexterity to the fingers.

Soon most of us felt that the good results were too little, and that all the training in exact observation and description, for which it was to be advocated, might be gained with much less expenditure of time, eyes and interest, from the observation of larger objects, having a more human value; for example, flowers and insects — yes, even the locust of newspaper fame. The scientific vocabulary we find it necessary to teach has also been gradually lessened, for we realize from our own experience, that in three or four years, when the boy goes to college, if he ever does, much of it will be out of date and common English generally does just as well. When the child feels the need of a word to stand for a new idea, we give it to him, and he is grateful and generally remembers it.

We used to do much dissection at first, but there has been a marked decrease of that done by the pupil in class except in elective courses. In fact, in a first year class, there is practically no time for it. The beauty of fresh animal tissue is so great, however, that the pupils ought to see at least one dissection under perfect conditions. A mussy, half dried dissection of an animal is a crime against children, for which there can be no excuse. Better one frog for four or five pupils, freshly killed, pinned out on weighted cork and covered with water, than one for each individual, not prepared as well as possible. The surprised pleasure with which one girl looked up from such a dissection, exclaiming, "Oh, aren't the colors beautiful?" quite paid for the trouble of preparation, and demonstrated the fact that a dissection is not necessarly distasteful to girls. In the human anatomy which follows the animal work, constant reference should be made to the frog dissection, if that is the animal chosen, and the educational value of the dissection will soon be demonstrated.

In place of the study of the anatomy of lifeless forms, the living plants and animals are now the objects of study whenever possible, and not only their structure but their activity is observed. In fact, physiology is emphasized throughout the course. Biology in the high school is becoming the study of life, not death.

Though discipline can not be the *sole* aim in our first year course, it certainly is a very important part of it, and we shall make a mistake if we so load the course that we do not have time to insist on the diagrams and descriptions which we do require, being well and carefully done. There is more training in one exercise well done than a dozen hasty ones, though of course hasty sketches may be useful for other reasons.

As a *third* aim, we are coming to realize the value of biology as a means of culture, i. e., it should broaden the life outlook; it should make a little clearer to the child his place in the living world, and the mutual dependence of plants and animals; it should give new interests to our city children.

That it will do this, was clearly demonstrated by what I saw of biology teaching and its results in Switzerland, ten years ago. Laboratory study of type forms, to give instruction in scientific facts and for training, was then the approved method in our American schools, and a textbook was rarely used at all — in fact a good one for high school pupils did not exist. I happened to board for five or six months in a pension in Zürich, Switzerland, where nearly all the boarders were Swiss or German boys, studying to become chemists, engineers, doctors, etc., in the University and polytechnical School. As it happened, we two American women were the only people in the house who were specializing in biology. I was increasingly amazed as time went on, at the general interest the boys had in the subject and their broad knowledge of plant and animal forms. I realized that the ordinary college graduate in America had no such interest, while our high school graduates from classical courses, similar to those these boys had had, knew nothing at all about biology. Finally, I determined to find out, if I could, how this result had been brought about. Visiting schools is not common abroad, but through the personal letters of Professor Lang and Professor Dodel, I gained permission to visit classes in five of the best Swiss schools. In one city I was refused admittance to one school, even with this introduction, the principal writing that visitors were always a disturbance and that no women had ever visited his school and he did not intend to introduce the innovation. My reception in the other Swiss schools was most cordial and I was given every opportunity to study their methods. In the forty recitations I was able to hear, I saw biology *for culture* at its best. The textbooks were well printed, with good diagrams and a marked absence of technical terms, there were excellent charts, fresh specimens for class use, finely prepared and mounted dissections in the school museums, and the school garden was universal. The teachers were men with broad university training. The pupils had learned their lessons and were very proud of their notebooks. Few American teachers whom I have visited are able to get an equal amount of work out of their pupils with so little apparent effort. I soon saw why my boarding house acquaintances had such an interest in the subject. I have no doubt that the all day excursions with the teachers, which are a school feature from childhood up, have much to do with the successful classroom work.

Biology for culture has now won a place as one of our aims in our first year work. We choose the objects for classroom study with this in mind, and the fine textbooks and nature books, which are appearing constantly, are making it more and more possible for it to be continued by the pupil after he leaves school. If we can give our pupils new and healthy interests for their leisure time, we are performing a much needed service. A friend recently overheard this remark from a genial, honest-looking traveling salesman, " Well, if a fellow doesn't drink and smoke and go out, life isn't worth living. There is nothing to do." Lectures and museums might form a variation from the theater and saloon for evening amusement, if there was a little interest there to attract at the start. Most city men will say, " I hate the country. There is nothing to do there." Every time we get our classes into the fields and parks, we are making them a little more at home there. Those are the red-letter days in biology and the ones that count for more in the lives of the pupils than weeks of paper correction, for they are giving them a new interest. Even if our pupils have been in the habit of going into the country, it now means more to them, as the casual remark of one matter-of-fact youngster, not especially distinguished for his scholarship — just an average boy — indicates. He was examining some leaf in the vivarium at recess and remarked, " Queer, isn't it, what a difference this biology makes in the way you look at things. When I went to walk, I used to see just trees and things, and now I wonder what is going on inside." One boy who had been hard to manage got greatly interested in his home work in germination and begged more seeds. He proudly brought in a bunch of radishes which he had grown. Another boy and his mother got interested in the pea seedlings and grew them in their tenement until the pods formed. When the pea blossom was studied, he announced that cross-pollination wasn't necessary. " I got some peas on my seedlings and there are no insects in my house to cross-pollinate." Forestry protection orations and debates in the upper classes demonstrate that the interest in trees has not died out with the completion of the biology course. All these interests tend for better citizenship.

A *fourth* aim was added when biology of the first year was made to include the mandatory human physiology. To teachers who were still clinging to the biology teaching for science instruction along evolutionary lines, this seemed a great catastrophe. " Three distinct courses," they said, " botany, zoology, and human physiology,— all in one year and with first year pupils. Impossible! " With physiology as the thread running through the year, this easily becomes the climax for which all the work of the year has been preparing. It is easily seen that an increased interest in outdoor life will improve the pupil physically and morally, but what connection is there between the study of a few plant and animal forms and the physical and moral health of the child?

If we have studied living plants and animals and emphasized physiology throughout the course by experiment and field work, the boy has learned to regard plants and animals as living machines. He has seen the same processes repeated again and again with some variation in the structure of the organs employed. The necessity of proper food and air, and of adaptation to environment has been seen in each case. When he begins the study of his own body, he soon begins to realize that he is simply a more delicately constructed animal, which depends for defence on his more intricate nervous system. If he chooses a city environment, then he must pay the penalty by using his brains to make his surroundings as nearly normal as possible. As he is subject to the same laws of nature as other animals, rules of hygiene are no longer to be regarded as lessons in ethics, but common sense deductions from his study of nature. Problems of sanitation and personal and city hygiene now interest him and that the interest is not confined to the classroom, the numerous newspaper cuttings and magazine articles which he brings in, bear witness.

Since the attempt to teach first year biology from a strictly scientific or evolutionary standpoint has been abandoned, we may be said to have thus far developed a threefold aim, (1) to give mental discipline, (2) to broaden the child's horizon and give him new interests so that he may develop into a happier man and more useful citizen, and (3) to make him a little better able to intelligently care for his own body in the environment where he must live and work.

This is a tremendous undertaking. How shall we best employ the time we have with our pupils each day? How can we help them most without doing their work for them? The laboratory manual was supposed to have solved the latter difficulty by making the child an independent investigator, but it certainly has its disadvantages, for the class will work unevenly, wrong conclusions will be drawn, unimportant points emphasized and the most important ones lost sight of, or never reached at all by some of the pupils. If it is used, the exercises set must be very short and plenty of time be left for discussion with the teacher. Teaching chiefly by use of a manual tends to become mechanical and nothing must come between the pupil and the teacher. If I try to teach your lesson in your way to my class, I shall surely make a failure of it. It will be very hard for a teacher to find a manual which exactly fits both him and his class. This is probably the reason why so many fine manuals are being published. Each experienced teacher, while he admires many points in the other manuals, finds that they do not quite suit his case, and so publishes his own lesson plans. Before the book is really in the market, he would probably like to write it over. These laboratory manuals are, however, of the greatest service to the teacher in home preparation, especially if he has had little experience. It is like visiting another teacher's class. We must, each of us, getting all the help we can, prepare our own lesson plans, that we may be quite in the spirit of them. Those of you who have read *The Lightning Conductor* will remember how he studied his guidebooks by night, so that he might take his fair charge over the best roads the next day, with the greatest pleasure and profit. She never suspected, you know, how he always managed to find the best view and discover the most interesting things, not realizing how much he had done in preparation.

We feel that we understand a little better than we did fifteen years ago, what biology ought to do for our pupils, but we would ask our critics not to judge our results by statistics alone. Our school authorities in New York city were wise in exempting first year biology from examination for graduation. You may test the facts a boy has learned and his manner of expressing them by a written examination, but how can you discover how much better physically and morally he may be as a result of the course? He may get 100 per cent on the scientific facts of the syllabus and make an exquisite diagram and yet not have gained as much as a boy who failed to get an average of over 60 per cent.

For those of us who are working on this problem, and are sometimes discouraged because of our inability to accomplish our ideal, I will give in closing, with his permission, Dr Cuthbert Hall's estimate of his twenty years' pastorate in Brooklyn. He addressed recently a congregation whose young missionary pastor he had visited in India. He urged them not to estimate their pastor's work by statistics, declaring that they would be most unjust if they did, as he was hard at work studying his people and their conditions. He was finding out what he was to mean to them. He was learning how to fit himself to their needs. Referring to his own pastorate, he remarked that the first ten years were spent in learning the needs of his people and his own powers, the next five years began to show results, but only in the last five did he accomplish anything really satisfactory.

SOME BY-PRODUCTS OF BIOLOGY TEACHING

BY BENJAMIN C. GRUENBERG, DE WITT CLINTON HIGH SCHOOL, NEW YORK CITY

In the manufacture of illuminating gas by distillation from coal, there is left a sticky, tarlike mass that was for years a source of annoyance to the manufacturers of gas, and to the neighbors of the manufacturers. It was a waste product that was not only of no value, but a perfect nuisance, since it had to be removed from the gas stills and disposed of in some way. It was thrown into the streams; which killed the fish and aroused the angry protests of the farmers; it cost so much to handle the stuff that it was a heavy charge on the manufacture of gas, but it was impossible to make gas without producing considerable quantities of it. This nuisance remained unabated until an experimenting chemist hit upon a method of using the nasty stuff for making certain brilliant coloring matters, which are now used by the ton for dyeing ladies' dresses and chromosomes. I don't know whether the price of gas to the consumer has gone down on that account, but it would seem that if for some reason it should no longer be worth while to manufacture gas for lighting and heating purposes, it might still be worth while to make the gas and blow it off into the air, just for getting the coke, the ammonia and the coal-tar, the by-products of this process. I am not prepared to quote the exact figures, but at the present time the substances prepared from coal-tar exceed in actual value that of the gas for which the coal was primarily distilled, by some hundreds of per cent.

Many modern industries are founded upon the by-products of other industries. We are so economical that not a scrap of material is wasted in the working up of cattle to make canned beef, glue, soap, glycerine, oleomargarine, sausage casing, fertilizer, shawl straps and I don't know what else; the total value of these by-products of the canning industry may or may not exceed the value of the net meat, but they are certainly worth saving. If they were not saved and utilized, it would mean smaller profits for those engaged in the business, or dearer meat for the rest of us, or both. If we should all stop eating meat, it might conceivably be still worth while to slaughter cattle for the other products, the by-products. My point here is simply that in the industries the by-products, or the potential by-products, may not be profitably neglected.

In the business of teaching, much doubt has been cast upon the actual value of the product, from time to time. There are men and women by no means stupid who question not only the value of college and high school education, but even that of the bulk of our elementary school education. There is great uncertainty in the minds of the public, and in the minds of many teachers too, as to the real worth to the children of the results of the various efforts comprised under the name of teaching. We hear a great deal about the three R's, and fads and frills, about preparation for life, and culture, and training for efficiency. And the only reason that any one of us who takes the trouble to speak up may get a hearing is, that we are all at sea, teachers as well as taught, and the parents of the taught. It may well be that the process has not been conducted economically, all things considered, that some of the possibilities have been neglected. We must look to the by-products.

When I speak of the by-products of teaching I do not mean the small graft in the way of sample copies of new books, or free tickets to an occasional lecture; nor do I mean the money you can make on the side because you have more leisure than the bricklayer; nor do I mean the glow of satisfaction that you feel when the minister speaks of consecrated lives, nor the gratification yielded by an appreciative word from a former pupil. I have in mind solely the value of the product and of the by-product of the pupil, that is, to the taxpayer, the citizen, the laity. While personally I believe that the value of work should be considered as much for the satisfaction of the worker as for the yielding of various utilizable products for others, I also believe that at the present time we are not in a position to consider any more than the latter aspect of our work.

Now in the case of biology teaching there is as great dissatisfaction as in any other line. One principal complains that we do not give enough information, and in the reaction against informational teaching many of us have no doubt gone too far in the direction of eliminating information. The business man concedes that the information that we do give is curious enough, but he does not see what its value is; and we must admit that it seldom happens that a business man is helped in urging people to buy goods by knowing that insects have three pairs of legs while spiders have four. The gentlemen and ladies complain that the information about frogs and horse-chestnut twigs may be interesting, but does not give culture, and a particular lady tells me that while her Eddy is just crazy to be outdoors and study flowers and bugs, he is very awkward in company and is unable to converse on literary and other genteel topics. And again other parents complain that while their children got along very well in the grammar school, and with all their teachers, they can not make anything out of high school biology. And so from every possible point of view the results of biology teaching are not satisfactory, with the possible exception of the practical applications that may be made of the results of physiology to personal hygiene.

Apart from information, the only important product that seems to be generally advertised is a certain training or development that is supposed to result from the exercise of the so called mental faculties, like observation, memory, reason and so on. But the psychologists, especially those that know the most biology, are telling us, have been telling us for many years, that the faculty psychology is all wrong, and that you can not strengthen the " faculties " by exercise the way you can the muscles; and our own observation may tell us that the pupils do not show greater ability in the use of these faculties because of their scientific training, except in connection with the materials and ideas they have actually dealt with in their studies. We are forced therefore, I think, to find some other justification for a continuance of our teaching, and I would direct attention to the by-products.

But when I speak of the by-products of this process I do not wish to imply at all that our primary product is of no value, or of minor or secondary value, though it may well be; I emphasize the by-products because we are in no agreement as to the primary product. What seems essential to one seems secondary to others. Under the circumstances it is necessary to catalogue the total product and then determine, each for himself, which he will consider the staples and which the frills, or which the main objects of his teaching and which the secondary objects. It must happen in any such cataloguing that the coordinate terms will be of very unequal value.

The first and traditional result of the educative process is knowledge. In the teaching of biology for information, there are a few groups of ideas, with their related ideals, that are of preeminent value.

In the teaching of physiology, whether plant or animal, a knowledge of the fundamental processes and conditions of life in general should be a major end. The knowledge of structure should be made subsidiary, and in the study of structure the emphasis should be on the degree of adaptation to function. If in the study of adaptation of organs the pupil can be made to feel that true worth is a function of efficiency, and that efficiency is a matter of adaptation to some purpose, there will have been established an ideal that is not biology: it is essentially ethics. I am not confusing efficiency with an ideal of efficiency; efficiency is a legitimate end of education, but I do not think we shall attain to the highest efficiency of anything but machines without this ideal; and the only study that can teach it adequately to pupils of the early high school period is, I believe, biology. But this result, though only a by-product, may not be neglected.

In the teaching of physiology there should be developed the idea of division of labor, and that of the correlation of functions. For example, I have found it worth while to get first year pupils to analyze a factory in their minds, to discover what the essential elements in such an establishment are. After the analysis is sufficiently complete, I ask them to tell me which is the most important factor or part of the plant. On the first impulses, many different details are mentioned by different pupils, but each suggestion is naturally met with objections from the others. I give them time to talk it out, and without any help beyond that of keeping them confined to the problem, they finally come to an agreement on the ground that where each part is essential every part is equally indispensable and therefore equally important. The results of this analysis are then applied directly to organs or organisms under discussion. Without ignoring differences in the relative magnitude or cost or intricacy of the several processes or factors, the pupils can get a very good idea of interdependence, of equality through difference; and this idea generalized is of great value in getting an organic concept of society as against the prevailing architectural concept. This is not biology, but it is a by-product whose value is not to be overlooked.

In the teaching of ecology there should be developed the idea that in addition to the dependence of living things upon certain factors of the environment, there is also constantly a struggle against certain factors of the environment. The pupil should understand clearly that the struggle is against inorganic factors and against organic factors; and here again the relations between merit and fitness should be emphasized. The study of the relations of plants and animals to their environments and to each other should be supplemented by the study of the relations of plants and animals to man. And in this connection the emphasis should be not on man the merchant, buying and selling, doing business, but on man the living creature that loves to live, without regard to buying and selling. In the larger cities especially does it seem to me very important to fight the prevailing commercial evaluation of the things of nature. The economic importance of plants and animals is mentioned in many of our textbooks and taught by many of our teachers. But too many of our teachers, in the textbook and out, too many of our pupils and too many of our leading citizens see in "economic importance" simply another term for "commercial availability." What is the economic importance of the crustacea? a teacher will ask, and be satisfied if the pupil remembers that the lobster industry amounts to so many million dollars, whereas the shrimps are not so important because — they are eaten only by Frenchmen. It is true that the human importance of lobsters and that of shrimps are approximately in a ratio that may be expressed in terms of the commerce in these commodities; but it is not true in general that the economic importance of any factor of our environment is commensurable with its commercial value. For example, we teach a great deal about the importance of respiration in the life of an organism, but it does not occur to us to speak of the economic importance of the atmosphere. Yet that is just what we should do, and we should place all economic references upon precisely the same basis, namely, the relation to human life and welfare. It is obvious that some of the most important things in human life and welfare have not yet been commercialized, and that the commercial test is as far removed from the human test as any well can be. Whatever, then, the pupils may forget of strophioles or echinoderms or centrosomes; whatever they may remember of angiosperms or parenchyma or trochanthers, of this I believe they can never know too much or too intimately — the intricate relations that exist between the life of man and the lives of other organisms: not in the way of the sentimentalist who will go without a drink to spare the protozoa in the water, but in the way of the master who consciously chooses, as a gardener, what he shall retain and what reject. This is not biology, it is economics — the economics of human happiness.

But in this emphasis on the human side of our subject lies a danger which it is the duty of the biology teacher to anticipate and to overcome, for nowhere else will the high school pupil have a better chance to meet it. I refer to the prevalence of the anthropocentric superstition. Every child brings this with him to school; some have lost a little of it and some have lost more, but probably no first year high school pupil comes entirely free of it. How many pupils leave the high school entirely emancipated from it? While I would constantly emphasize the human possibilities in all the material and ideas utilized in the course, I would just as constantly knock, knock, knock against the notion that these usable and these undesirable things exist because of man. In the teaching of plant and animal physiology there is always opportunity to contrast the *function* of an organ from the point of view of the organism, with the *use* of the organ or organism from the point of view of man. To learn that the progress and welfare, yes, the very existence of man in the midst of his various needs and of the various obstacles to his satisfying his needs, are not the results of a world having been made for him to suit him, but are the results of man's own knowing and doing; to learn that man's mastery of his environment comes only through perpetual striving in thought and in action, is to learn something of which we can not afford to leave any person in ignorance. Whatever else the pupil does or does not learn in school, I believe that this one by-product is of sufficient value to justify the erection of the plant; and I don't know where the pupil can more easily get the results than in the biology course. But this is not biology, it is cosmology.

One other aspect of information that should never be ignored is the teaching of the idea of evolution, with the implanting of the related dynamic ideals. And by evolution one need not mean Darwinism, nor Lamarckism, nor any other special attempt to formulate the process. But if the pupil does not get from his high school biology the evolutionary idea and the dynamic ideal, he is most likely to go out of school without these things, for I don't know where else he can get them. Certainly not from his language work, with its complex rules and interminable exceptions; not from that series of more or less fortunate catastrophes that is taught him under the name of history; not from the adventures and romances that constitute the bulk of his literature; only *possibly* from his mathematics, except for the fact that the laws of mathematics are *so abstract and* so absolute, so relentless, and therefore so far removed from the apparent chance and irregularity of everyday affairs, that the pupil is more likely to conclude that law is something that exists only in the textbooks and in heaven. The idea of order, the idea of causality, the idea of unity, the idea of constant change, and the ideal of progress, the revolt against the doctrine, "As it was in the beginning, is now and ever shall be," in its ordinary static sense — these things are not biology, but a valuable asset to every person, and a possible by-product of biology teaching.

Biology has borrowed from social science three ideas that have influenced its development profoundly. The idea of evolution, the idea of division of labor, and the idea of struggle for existence have been thus borrowed, with what results we all know. It is the duty of teachers of biology to return to society these ideas, with the compound interest of broadened application and fuller, more definite content.

If we reject the faculty psychology, as we must, we need not reject with it whatever benefits may accrue from the formation of useful habits. The method of the laboratory has been lauded for its remarkable effects upon the character of its devotees — or victims — and much has no doubt been credited to the laboratory that properly belongs elsewhere. But I think there can be no question as to the value of saying clearly and exactly what one means. If the laboratory is not the only place where this habit may be acquired, it is for the high school pupil the place where he can get the greatest amount of practice in this exercise, and under the most valuable control, the control, that is, of the objective limitations to the thoughts he is trying to express. Indeed, I sometimes think that too large a share of our teaching time is taken for doing the work that should be divided among all the departments of the school and which, it sometimes seems, is most systematically neglected by the English departments. The especial advantage of doing language work in connection with the objective material is generally recognized. At the same time we may be tempted to overestimate the importance of getting from each pupil a complete and accurate statement of what he has seen or thought. While we may be sure, when the pupil makes such a satisfactory statement, that he has seen that of which he speaks, we may *not* be sure, when the pupil can neither describe nor draw nor model that which he is supposed to have seen, that he does *not* understand it. And this for the very simple reason that not only does expression follow im-progress. Yet it often follows at a very respectful distance. Every one of us knows that in the efforts to learn a foreign language, a stage is reached at which one is quite able to understand a rather long and complex sentence, without being able to formulate correctly a much simpler sentence in the foreign tongue. It may be the same with our pupil: he understands a great deal more than he is able to tell, and the difficulty of the teacher is to know when the pupil *understands* without waiting until the pupil can also *tell* what he understands. Yet if we have to wait for the telling, we have a by-product of great value. But this is not biology, it is expression, graphic or linguistic. And the expression learned in the laboratory has the recognized advantage that it operates under conditions that permit of immediate and constant objective control as to accuracy and adequacy.

I am not sure that science teaching does, as is often claimed, inculcate a love of truth. But I do feel sure that science teaching may impart a keen realization that there is a difference between truth and error which is quite independent of opinion or authority. It may perhaps stimulate in some cases a languid self-reliance. If the question the pupil is moved to ask by a suggestion from the material with which he works is promptly and satisfactorily answered by the teacher, there is great saving of time for the teacher, there is great increase of knowledge for the pupil, and everybody is happy, except a few cranks. For the more the pupil gets information by the mere asking from his teacher, the longer will it take him to learn that the only way the teacher found out was by looking at the material himself or by reading what some other looker had written; the longer will it take him to realize that he can find out more directly and more certainly without asking; the longer will it take him to throw off the superstitious awe for the authorities that have acquired their wisdom in some mysterious way supposedly beyond his reach. It is not necessary that the pupil be left with his specimen and his own resources "to observe," but it is necessary that no opportunity be lost to teach the pupil that most of the questions he asks he can answer for himself; to teach him that the opinions of men and women are of worth just in proportion as they are founded on sound knowledge and on sound inference. To teach one that his own brain with its peripheral organs is an apparatus that can create knowledge as well as that of the writer of textbooks, and to develop a habit of looking to this apparatus for first aid, instead of the habit of asking someone else, that is not teaching biology, it is teaching self-reliance in thinking; and this by-product alone is worth the price of admission.

But it is not enough to think boldly and independently; it is necessary also that the thinking be logical and coherent. The study of grammar is under certain conditions nothing but the study of logic, but it is so formal and so attenuated and so much restricted by the special rules, that it is very uncertain, in regard to the pupils who attain high ratings in grammar, whether they are those who were better thinkers before they began the study, or those who acquired the art during the course of the study. On the other hand, the logic of the laboratory, like the expression of the laboratory, is constantly subject to the external, impersonal check. The method of the experiment leaves no room for opinion where certainty is possible. We hear it often objected that the method of science, meaning the method of thought in science, is all right for those who are to pursue the study of science further, but is of no use to the pupils who leave the high school at the end of one or two years. From this view I must dissent, and for the following reasons.

The pupil that becomes a scientist does so only on condition that he is prepared to meet in his problems, prepared, that is, to think as a scientist. But the student that goes into the shop or the factory or the office without any more schooling than he gets by the end of the first or second year of high school, is still to become a citizen and a worker, and it is especially from the point of view of the citizen, who is called upon without any special preparation to declare periodically what shall or shall not be the policy of his city or state, and who shall or who shall not be intrusted with carrying out the will of the people, that the method of science can be of tremendous value. The habit of analyzing complex phenomena is of value to every man and to every woman that has to live in an environment complex enough to support human life. This habit is to be acquired only through the practice of analyzing complex phenomena, and will be regularly exercised only where there is a live realization that phenomena *are* to be analyzed. And nowhere in the school course is there presented an opportunity for such analysis, or for realizing its importance, like that furnished by biology teaching. Very few of the pupils that enter high school ever get a chance to study economics or any other branch of social science; yet every young person that lives long enough is expected to have opinions on the most complex of problems, and that too when most people are not even aware that there is such a thing as analyzing a problem. They have heard of analyzing water from a suspected well or of analyzing adulterated food; but they don't know anything at all about analyzing the tariff question or the open shop question or the equal pay question. Of course I do not refer to the fact that they do not use the word "analyze" in this connection; but I do refer to the fact that they do not realize that there is such a process and that it must be applied to every question. Now I do not claim that the study of biology will make pupils competent to pass sound judgments upon the public problems that confront the citizen, but I do claim that a habit of analyzing complex problems, the habit of looking for the factors or elements, is a decided advantage in meeting such problems, and this habit our course might establish more or less firmly, by our calling attention to the function of analysis in the activities of the physician or the engineer or the statesman, and to its function in the solution of the thousands of problems that arise in the practical conduct of each individual's affairs. This idea of analysis and the habit of analysis are of great value, but they are not especially biological.

In this connection our old friend the faculty of observation deserves a brief notice. It is quite certain that practice in the observation of flowers and bugs does not establish the general habit of observing everything that comes within the range of our senses. But it is equally certain that a realization of the importance of certain classes of facts will make one both diligent and careful in the gathering of those facts. Now we can make the pupil realize that a knowledge of facts is essential to the solution of various problems, and that the facts are worthless unless they are the results of careful, accurate observation. Beyond that we can only make him familiar with types of structures in which he will discover details and variations more readily after practice: we can never teach a boy to take in at a glance his sister's new millinery dream by the application of the laboratory method to the inside of a crayfish.

The habit of looking beyond facts to their possible significance is another habit that one may conceive to be of value to the person that will never have anything to do with the pallial sinus or fibro-vascular bundles; and the practice of distinguishing between facts and inferences is one that could be of use even in the kitchen. These are matters that may be acquired in the study of language or history, but I believe that the high school pupil has no better chance to get them than is furnished in the biological laboratory. Yet these products are not strictly biological, they are metaphysical rather, or psychological. Finally, the habit of verification of inference and hypothesis may be established in the laboratory, and once established is an invaluable protection against the browbeating of conventional conservatism on the one hand, and against the allurements of yellowness on the other. And this product too is not biological.

All these methods of science — analysis, observation, inference and verification — will not become fixed habits of pupils unless a special effort is made to generalize their applications to the affairs of the trades and the professions and the interests of everyday life; and biology furnishes the best basis for such generalizations, being on the one hand complex enough to be safe for analogies to practical affairs, and being on the other hand concrete enough to allow of objective and experimental study.

One might be tempted to ask whether I would teach anything in the biology course that is really biological, or whether I would leave anything for other departments of a school to do. To answer the latter question first, I would say that I believe that every subject in the school must contribute its share towards the inculcating of certain ideals, towards the establishment of certain habits of thought and action, and towards proficiency in the arts of expression or communication, in addition to the imparting of information proper to its department. That there are biological matters to be taught in the biology course goes without saying, but these other things to which I have referred are some of the by-products, actual or potential; and we cannot afford to ignore them.

To summarize, I should like to present this plan or ideal for utilizing the by-products of biology teaching:

Teach for thinking, as against merely remembering or believing;
Teach to think straight rather than loosely or crookedly;
Teach to think to some purpose, rather than diffusely, vaguely;
Teach to think to some human purpose, as against merely personal or commercial purpose; and finally,
Teach for an ideal of a dynamic human purpose, as against a static one.

Section C — EARTH SCIENCE

THE USE OF A WET LABORATORY IN PHYSIOGRAPHY TEACHING

Illustrated by lantern slides

BY OSCAR D. VON ENGELN, CORNELL UNIVERSITY

Instruction in a natural science may be broadly divided into lecture work and laboratory work. These terms are inclusive, for under the first heading will come lectures, recitations, and seminary reviews of literature; in general then the acquiring of knowledge of the science from the investigations and the formulations of others; whereas in laboratory work we ask of the individual that he deal with the material itself, make his own observations and draw his own conclusions. Thus we may include field trips, conclusions drawn from assembled data, and laboratory experiments all under this one head.

At first thought it would seem an easy matter, given these elements, to outline a course of instruction which would be adequate to cover the specific need. But difficulties are encountered at various points which are not always of the readiest solution. It is a general impression that in the university the teaching of the subject-matter of the science, rather than its disciplinary value as a study is the chief objective, whereas in the secondary schools a science subject is of value especially as it trains the faculty of observation.

Assuming for the moment that this impression is a correct one, it would seem that, granted the lecturer's knowledge, and the soundness of the text used, the task of university laboratory teaching would be less difficult than that in the secondary schools in the same branch, for on a presentation of the subject-matter the student ought to be in a position to appreciate and follow the laboratory work with interest and profit.

But even if this be true, the deduction drawn is far from being a true one. As a matter of fact the problems are essentially the same, here and in the secondary schools. Powers of observation and deduction acquired in one science, do not necessarily imply the same ability in another; especially in the case of the immature student. If the training of this faculty is the object of the laboratory work of the secondary schools, this same object combined with an intelligent and broad understanding of the subject is the object of the same work in the university; and the means must be the same.

Here at Cornell, in our laboratory teaching of physical geography, we put the emphasis on, and devote all possible time to, field work. The region is one particularly rich in material, and the opportunities to study a diversity of phenomena are great. Therefore we spend the most possible time in the field, in the fall and in the spring; and we pride ourselves on having developed for the vicinity a series of excursions which are at once comprehensive and intensive. It is in the latter phase that this class of instruction is weakest, for its success is dependent on close observation by the pupil, and the instructor should really be at once an authority in the science, and a teacher of the highest order. Such paragons may exist in numbers among you, but unfortunately elsewhere they are rather rare.

In connection with this field work in physical geography I have found difficulties of two kinds. The one is that the concepts of space, for example the wide area of perhaps hundreds of square miles of a river system, is beyond the imaginative capacity of the beginner, and as a consequence there is a failure to grasp the relationship of the phenomena discussed. We endeavor to overcome this as much as possible by taking the class to high points, which are available here in the hill summits. There may be a suggestion in this for some of you who have also realized this inadequateness on the part of the pupils. Second, there is often the impossibility to convey an appreciation of the result, even when one is at the point where the processes are going on. An example is the postulate that a river must have tools with which to work in carving its valley. The class gazing into the quiet stream can only be told of these tools, and referred to the flood time and its conditions, when their appreciation is dependent on former individual observations. The sum of these difficulties may be compared to the confusion encountered in experimental physics, where the intricacy and the complexity of the apparatus, the number of cocks to be opened and closed, and the mechanism of the often ingenious schemes which have been devised for the securing of quantitative readings or other data, obscures and often diverts the pupil's attention from the real object of the experiment.

Therefore in the indoor laboratory there ought to be a clearing up of the field observations, and a concrete presentation of phenomena not available in the vicinity, or of such a kind as do not permit of actual observation in the field.

The indoor work begins well with a study, as detailed as the nature of the course will allow, of the materials of the earth's crust on which the natural forces are working, and which they produce, i. e. the minerals, the rocks, the soils, and phenomena such as concretions, geodes, ropy lava, etc., which occur.

But by what shall this be followed? Work on contour and hachure maps, the making of a series of profiles and cross-sections? That is practically the gist of the laboratory manuals of physical geography now extant, though there is included some work on models and a number of experiments of meteorological and astronomical kind, which two latter phases we do not treat here, as there are courses given in the university in these subjects.

The use of models is excellent, and their value has long been recognized, so that it is not necessary for me to consider these further than to mention the objections of their frozenness, that they represent the arresting of a process which implies change; and second their nonavailability in great variety.

But to return to the map work. Of what use is it to cross-section contour maps, when the student has but the faintest conception of their meaning and interpretation? This may seem an exaggeration, but I have reason to know that it is not.

Here comes then, first, a place for the wet laboratory. In it the significance and the direction of contour lines can be made clear, as no amount of hypothetical submerging of a boulder or a hat will. We will pause for a moment then to describe the laboratory and the apparatus that we have at present.

The whole equipment was conceived by Professor Tarr, but wholly in a tentative way; as the lack of any previous published work of the character necessitated going ahead according to his judgment as to what would be needed. And so far as our beginning attempts indicate, it entirely covers the needs for the simpler experiments at any rate.

It consists first of a wooden tank, water-tight, some 10 feet square, and 18 inches deep. Inside this is another tank about 6 feet square and 12 inches deep, which can be raised and lowered at will, and tipped to any angle inside the former. The larger tank is to hold the waters of the experimental ocean or lake while in the smaller are built up the land forms. When the building of a certain form is complete the sides and ends of the inside box can be removed if necessary. Then there is a long narrow tank, with dimensions, 20 x 2.5 x 2.5 feet for experimenting on long river valleys; and third a double tank in a separate room whose temperature is to be under control for glacial experiments. These tanks are also about 10 feet square, but while within one another, they are almost of a size, and some 4 feet deep. Water pipes, sprays of various kinds, and screens for sifting material are also provided. The material we have used to date is clay, molder's sand, sand and pebbles, and plaster of paris.

I will not weary you with the details of the experiments we made to determine what thickness and kinds of layers of strata we needed to use to get the effects desired, but only incidentally call attention to the requirements in discussing the experiments.

These are to date all intended to serve for instruction in an elementary class, although provision is also made for research work to begin soon.

We may then come back to our contour experiment. For this we use the shallow square tanks. Nothing could be simpler than to build up a land form, with hills, embayments, and valleys, and then removing the sides of the inner tank, raise the water surface until it just touched the outer periphery of the land form. The pupils are now instructed to draw the line of the water level on a scale of 1 inch to 1 foot. Then the land is lowered one inch, and another outline is made. With successive lowerings we finally have only the circles and ovals of the projecting hill and ridge summits to put in, and as a result each student has a contour map with a horizontal scale of 1 inch to 1 foot, and with 1 inch contour intervals. The dullest of them can not fail to appreciate the significance of such a map. With this apperception basis (if you will pardon the term) one can with profit set them to cross-sectioning the map they have made, and then to cross-sectioning and profile drawing from topographic sheets.

Our experiments to date have been on the erosional work of streams and waves. We found here that to get results in a short time, nothing more resistant than a clay layer could be used. When plaster of paris even in small proportions was used, the resistance to erosion was such as to make the effects inappreciable after a number of hours of spraying. Again if a heavy clay layer is on the surface, and the angle of slope is moderate, the erosive limit of the developed stream is soon reached, and after that only clear water purls down the valleys. This condition affords opportunity for a very pretty demonstration that streams do their cutting with tools, for by stopping the spray, and sprinkling on a layer of sand at the head waters, and then resuming operations, we note that the streams now have abundant sediment, and moreover they are cutting back the clay of their middle and upper courses. Again in their lower courses the streams are now overburdened, and as a consequence building up their channels, i. e. aggrading, in order to get a slope steep enough to enable them to carry their sediment load.

If we could demonstrate no more than these few things, we would consider the wet laboratory as amply repaying its installation. For an aggrading stream is a difficult conception with students in itself. But these are only a small part of its possibilities. In the cutting down of one land form many other phenomena can be observed. Thus one of the first and most striking things that one notes, is the extremely wide distribution of fine sediment of a clayey nature, which, even with only one small stream running and the outlet of this stream near the point of discharge of the water from the ocean, yet settles all over the ocean bottom. Thus one can clearly demonstrate the possibility of a vast expanse of stratified rock as due to the deposits of streams entering a former body of water.

Deltas are land forms, which because of their fertility and topography are of the most important geographic controls in the history of man. Yet their slopes and construction are one of the difficult things to make clear in the field. But in the wet laboratory we were surprised from the start by the perfect development of this form which we secured in each case. One could see perfectly how the coarse particles were dumped down the steep slope, the finer clayey material shooting out into the water, and the swinging back and forth of the distributory channels. Again when the material was in the aggregate coarse, the deltas took a crenate outline, whereas when fine they had a smooth curved edge. This has a bearing on our fossil deltas hanging on the hills, composed of coarse glacial gravels for the most part, for these too have the crenate form. As to form, part of the delta could be seen through the water, but it was readily possible to lower the water surface, and disclose the whole. If at this lower level, the spray is started again, we get the condition of rejuvenation, with cutting through of the delta and intrenched meanders in the upper courses.

Other possibilities which suggest themselves at once are the development of alluvial fans, formation and recession of waterfalls,
holes, head water erosion, gorge forms, mature stream courses,
ating meanders, plantation, river piracy, flood plains, and so

on, ad infinitum. Just one more idea and I have done with this part. It is a popular notion that bays are cut in sea and lake coasts by waves and the entering streams, and the contrary, true idea, that these agencies tend to straighten out the coast and obliterate the irregularities is hardly known. Nor can this phenomenon be well shown in the field. Yet this is again one of the most simple things to show in the wet laboratory. The logic of it is irresistible after the pupil notes the waves tearing down the coast, while the currents they generate inevitably fill any original indentations which may exist. At the same time the small irregularities, as sea caves, due to wave work on material of different resistance, can readily be shown, and also how these are distinct from the other larger phenomena. The influence of joints on cliff formation is here immediately suggested.

But it must not be imagined that a wet laboratory necessarily implies only running water experiments. Far from it. Even now we have projected the construction of an experimental geyser on Bunsen's principle, a volcano wherein a chemical mixture, buried under strata, supplies an expansive, viscous, eruptive lava, and a repetition of some of Mr Bailey Willis's experiments in the folding of strata in mountain making. Professor Tarr has also some glacial projects which can not help being instructive. When eventually we get a good series worked up in form so that they can be repeated in schools without too elaborate and costly apparatus, we hope to publish them in the form of a manual with a suggestive outline for work.

DISCUSSION: LABORATORY WORK IN PHYSIOGRAPHY. ITS ADVANTAGES AND DANGERS

BY MARY GERTRUDE SULLIVAN, MASTEN PARK HIGH SCHOOL, BUFFALO, N. Y.

That physiography requires carefully planned laboratory work, as well as field work, for its highest development, has been the opinion of progressive teachers for some time past. Since our true aim in the high school should be development and character building rather than the storing up of facts, nowhere in the curriculum can we find a subject better fitted to our task. Physiography is broad. It involves the understanding of so many related subjects; astronomy, geology, meteorology, lithology, ethnology all contribute to it. The student must be made to realize that physical environment controls living forms and that living forms respond to this environment. The necessary relation which exists between the physical world and man is quickly recognized by the pupil, when he is brought face to face with reality. After all it is reality that educates, and in his observations he sees truth at work. This, then, is a splendid field, and well suited to our junior students in the high school.

Lest some of us might hope or expect to have indoor laboratory work take the place of, or substitute true field work, let me make a plea for the latter. The real observation of natural phenomena is of greater importance, in that it brings the student face to face with "that which is." Nature works slowly, precisely, systematically. She is simple, exact, never obscure and when approached with earnest questions reveals herself. If the pupil has made careful and accurate observations, simplicity, truth and wisdom must follow as a natural consequence. Nature will also make him sympathetic as well as systematic and a good foundation is laid for future work. The student should be led by careful planning to observe, collect data, separate the essential from the nonessential, compare, discover the principles underlying phenomena, and see the relation of cause and effect. He must be accurate and honest in his investigations if he wishes to get true notions and the ability to think correctly. This arouses enthusiasm and a love for work. The student turns from rounded pebbles, crumbling rocks, rushing waters with eyes wide open and with eyes that are never again closed to nature. Out of doors is the true laboratory for the study of physiography and with the assumption that every teacher has from six to ten well planned field trips, let us pass on to indoor laboratory work.

Here, too, we must open the eyes of our students to the great harmony and system of the physical world.

The teacher should be well prepared, at ease with his subject and above all, in love with it. The pupil is quick to catch the enthusiasm of the instructor. He becomes interested and willing to follow his guidance.

Indoor laboratory work can do little more than supplement field work, by stimulating in the student a direct interest in all that surrounds him and by fostering in him a desire for research, clear, accurate notions and a love for law and order. This interest once awakened is lasting. Try to inculcate in the student a desire for individual work, both in the laboratory and in the field, and reward his efforts with encouragement and suggestions.

Every means that the teacher can procure whether invented or borrowed should be brought to his aid. The equipment of our modest laboratories is at present inadequate and perhaps it is well that this is so.

Expensive, complicated apparatus is not necessary nor advantageous. Have simple, durable material, the best globes, maps, charts, models, a liberal collection of typical rocks and minerals, books for collateral and supplementary reading, contour maps, pictures and diagrams. Do not load the room with lumber which looks scientific, but which is rarely or never used. Add each year to your store, several pieces that you know how to use advantageously, and in a short time you will have a well equipped workshop. Add when possible a lantern and a wet laboratory. Let us consider and freely discuss some of the advantages of laboratory exercises in the developing of science and finally in the development of character building on the part of the pupil. Our students come to us with the ability to learn by rote, and with little power to think. The young child learns so easily by this method, that teachers, all along the line, have taken advantage of it, and unfortunately some high school teachers continue the process. He dislikes to stop and think, and has few concrete notions. In many cases he has lost his orientation with regard to the forces which surround him and it is the province of the teacher of science, and the function of the laboratory to build up common sense notions, and to lead him to discover truth by thinking, reasoning and seeing the relation of cause and effect. He must be made to realize that lasting knowledge comes from investigation. Ask your young first year pupil to give you a definition of any common geographical feature, for instance a valley. He will recite it glibly enough. Now ask him where he has seen one. In the majority of cases, he will tell you he does not know whether he has seen one or not. Some of the more courageous will risk one in Pennsylvania, Virginia or even California, never one in their own locality. They are positively astonished when they find so many near at hand.

Ask on how many days in the month, all conditions being favorable, can the moon be seen. You will be surprised at the variety of answers. Then let the pupil take a planetarium and work out the problem. Next require careful observations for a month and you will be delighted.

The great advantage of laboratory work is that it gives concrete notions. The student must concentrate his attention upon the material at hand, struggle with the principles involved and by questioning and reasoning, cause the problem to fall apart. He is enabled to meet his conclusions with a mind more and more logically trained and thus he is fitted to enter upon a more difficult task and ready to comprehend its full meaning and significance. As he is required to work and investigate for himself, this gives the restless adolescent a kind of manual occupation which quickens his interest and makes him in a measure see the relation which exists between the earth and man. With a little encouragement he will gain confidence in himself and realize that there is a delight in intellectual power. His energies are turned toward self-education and a healthy attitude regarding duty. He becomes an important factor instead of an individual inhabitant of the class. Difficult problems challenge him and he turns his energies toward them with new power. A healthy curiosity is aroused and he wishes to satisfy it. As laboratory work holds his attention and interest, it is both a preparation for and a review of book work.

In the study of minerals and rocks he must observe closely and accurately, look for fine differences and compare, and this cultivation of the powers of accurate observation is one of the essential elements in his education. By means of contour maps he is brought face to face with all the important features of nature and he is able to understand the influence of environment.

When the pupil reviews his subject he looks from a broader horizon and is enabled to retain the essentials.

Encourage the pupils to make individual models representing some fundamental idea in the lesson. Those who have crude ideas can not do this at first, but those who have vivid imaginations will work out their ideas and benefit the whole class.

Let the pupil explain his model to the class, and if there is a mistake give him the first chance to correct the error. If he does not see it, some live mind will discover it for him. This gives the student confidence and power and keeps the teacher supplied with good material. The taking of weather reports develops the ability to judge correctly, and by observations and correlations he discovers the laws of meteorology.

Are there any dangers to be encountered in this apparently splendid method of presenting physiography? Yes. There are a few. Wherever there is great enthusiasm there is also danger. The teacher, first, must keep in mind, that laboratory work is not an end in itself, but only a means to an end, and that the better understanding of the subject-matter of the textbook.

It should never be made spectacular nor fall to the plane of entertainment. If there is a scattering of attention and energy, it is a waste of time, and should come to an end at once. Then let written work bring out that which the pupil has culled from his investigations. The work may be too technical for first year pupils.

If not guarded against the pupil develops a disinclination for textbook study. The weaker ones are not challenged by the difficult problems presented, as they feel sure that in the laboratory they will be made clear. There is also danger of doing too much, thus causing the pupil to take time and energy from his other subjects.

The work may be interesting and have no real value. The teacher is likely to give too much time to one topic and sacrifice another. For instance mathematical geography, which is taught in the grades, should only be reviewed and referred to from time to time, but most of our students have such vague ideas that it is necessary to develop the whole subject again.

But laboratory work is essentially doing and the labor of preparation and supervision is richly repaid by the responsive interest on the part of the pupil.

The student takes that which the teacher has to give, no more and no less. Let us send our trusts out with a love for investigation and truth. Well balanced characters must follow as surely as the night the day, and our students will revere, through nature, nature's God.

Friday afternoon, December 27

Section B — BIOLOGY

THE WORK OF A CHILDREN'S MUSEUM

Illustrated by stereopticon slides

BY ANNA BILLINGS GALLUP, CURATOR CHILDREN'S MUSEUM,
BROOKLYN INSTITUTE OF ARTS AND SCIENCES

As the work which I represent is not conducted exclusively for high school students one may reasonably ask why a children's museum should be discussed in a meeting of this character. My answer to such a query is that the children's museum exists for children of all ages, from the infant in the kindergarten to the high school senior, and that in proportion as it can help us to a wise and more sympathetic understanding of young children, will it serve as a means of achieving finer results in high school instruction.

As an institution the Children's Museum is only eight years old, and its unique character perhaps calls for a word of explanation about its origin and early history.

It was opened in December 1899, as a branch museum of the Brooklyn Institute of Arts and Sciences, in an attractive residence of a beautiful suburban estate which the city had taken as a public park, the Brooklyn Institute having originally leased the building as a temporary storeroom for collections.

Upon the opening of the new Museum of Arts and Sciences and the consequent transfer of the most valuable property, there remained a few insects, stuffed birds, and mammals principally from Long Island, which were utilized as a nucleus of the Children's Museum collections. Thus the work began with an empty building and the meager exhibits above mentioned.

The manifest pleasure with which children began to use the new museum and its facilities pointed to the necessity for clearly defined plans for expansion.

In outlining such plans the Brooklyn Institute trustees expressed heir purpose: (1) To form an attractive resort for children with luences tending to refine their tastes and elevate their interests. To create an active educational center of daily assistance to pupils and teachers in connection with school work and to offer new subjects of thought for pursuit in leisure hours.

The aims and purposes of such a museum called for: (1) The preparation of collections which children could enjoy, understand, and use. (2) The arrangement of material pleasing to the eye and expressive of a fundamental truth. (3) Brief descriptive labels expressed in simple language and printed in clear readable type.

There was also demand for a system of instruction which children would voluntary employ.

Time and experience have been necessary conditions for the execution of the original plans thus laid down. As a branch institution, the Children's Museum derives its income for maintenance from the annual appropriation made by the city of Greater New York to the Brooklyn Institute of Arts and Sciences. For the enlargement of its collections it depends upon the work of its museum staff for the collection of materials, and upon the modeler, cabinetmaker, artists, and taxidermists of the Central Museum for highly specialized labor, while the money used in the purchase of new specimens is granted, by special appropriation of the trustees, from a general museum collection fund, composed of private donations and legacies.

After eight years of growth the Children's Museum of today occupies the entire Bedford Park Building, comprising 12 exhibition rooms, a lecture hall, and a Children's Museum Library.

In the exhibition rooms are collections of natural history, geography, United States history, and art, to which children and teachers make constant reference.

Our natural history collections distributed in five different rooms are arranged for children of varying ages.

A synoptic room assists the high school and normal school pupils in studying zoology, while the local collections of amphibia, reptiles, and birds, delight children of all ages.

A room of animal homes contains the nests and family groups of common Long Island mammals and birds, and in the bird room, besides the common migrants, are the condor, lyre bird, cassowary, albatross etc., grouped in a case labeled "Birds We Read About" — where are also appropriate quotations from the authors who have written about these birds.

Our insect collection contains a systematic series of the moths, butterflies, beetles, and other insects of Brooklyn and vicinity, each specimen accompanied with a label giving the common and scientific names, the sex, and the locality. General labels noting group characters are placed in each section. There are also little model groups picturing what insects do and special exhibits illustrating mimicry, protective coloration, and life histories. An observation hive of bees, a colony of ants, and the various water insects in aquaria are of almost daily use to nature study classes.

In order to make our mineral exhibit pleasing to children we illustrate the economic uses of minerals by displaying mineral products with specimens. With quartz are amethysts and crystal lenses. Flower of sulphur, roll brimstone and matches, with the sulphur crystals form a part of the sulphur exhibit; gypsum is shown with a plaster of paris model, and pictures of mines and processes of manufacture are freely used. Brilliant and beautiful minerals are used for their esthetic effect.

Our museum contains a small historical exhibit which began with old relics, and arms and weapons, formerly used in the wars of our country. These have been chronologically arranged, supplemented with charts and pictures, and more recently with model groups to illustrate the period of colonization and settlement. Six of these groups are now installed, each representing one of the types of European colonists who effected permanent settlement in the United States. In order of their settlement these were the Spanish, French, English, Dutch, New England and Quaker types. There is something about these miniature scenes strikingly engaging to the child. They stimulate him to close and repeated observations and comparisons, and with the help of the childish imagination carry him back into the period to which they belong.

While charts, globes, and maps are used in our geographic exhibits, the model group method has been adopted for bringing together the remote peoples of the world. By means of these miniature scenes human beings appear under extremely unlike conditions of climate and physical features, both of which determine appearance, dress, industries, character, and other distinctions.

The relation of man to his environment as shown in his place of settlement, his occupations and industries as determined by the climate and physical features of his surroundings, and his intercourse with his fellow men are important relationships not always clear to children who study merely globes, maps, and pictures, lacking in that dramatic quality which is an important factor in *linking the* childish imagination with what is new and strange.

Each scene chosen depicts the natural physical character of the race represented. It shows the members of the family in characteristic dress, the home, and its surroundings, including useful domesticated animals, implements and tools, and men at work. We have begun this series of geographic groups with a choice of those peoples whose mode of life are least complex, since it is among such races that the dependence of man upon his physical environment is most clearly shown, his food, clothing, and shelter often coming from a single source.

The important underlying principle to be emphasized in exhibits of this character is that of relationship. The child is ever ready to put himself in the place of the lilliputian being whose environment he now sees spread out before his eyes. What his far away brother has and what he can do, are to him important subjects about which he asks many questions.

We try to get in touch with children through the schools, for experience shows that the best results are obtained through cooperation with enthusiastic principals and teachers. Our exhibits are therefore correlated with the public school work, and lectures supplementing grade courses of study are regularly given during the school year. Pupils are informed of these lectures through the *Museum News,* a monthly publication which is mailed to the principals of the schools, and once they begin coming to the museum they usually continue their visits.

Between the hours of 9 a. m. and 5.30 p. m. on every week day and 2.30 and 5.30 p. m. on Sundays when the museum is open, children are welcomed and encouraged to the fullest enjoyment of every attraction.

A Children's Museum Library which occupies two rooms in our building and forms a part of the museum work contains about 5000 volumes consisting of the best works on natural history in its broadest sense. The library provides books of information for visitors and in offering books on the lines of school work forms a valuable school reference library adapted to giving assistance to teachers and pupils. The two trained librarians permanently in charge of the reading rooms enable visitors to consult books without formality or loss of time.

In the absence of official relations with the public schools, the museum attendance is exclusively voluntary. Children and other visitors usually arrive with some definite end in view and the members of the staff endeavor to assist toward that end.

We try to give our visitors the same freedom and pleasure that they would experience in entering a delightful home where every plan is for the enjoyment of guests. Members of the staff are always ready to receive visitors, to answer their questions, take specimens from the cases for closer examination or tell stories to younger children.

Our boys and girls have learned that the museum will help them over many a hard task assigned by their teachers, and thus the work of the museum has become as diversified as the individualities of its visitors.

Principals, teachers, and parents unite in their testimony as to the quickening influence of the museum on the mental growth of the children, and an increasing number of teachers find time to bring classes for supplementary half hour talks. Additional credits in school are frequently offered to pupils who give satisfactory evidence of having profited by their visits. The museum makes no demand on its visitors.

It offers its privileges free to children of all ages and leaves each one to choose his own method of enjoyment. Whether he copies a label, reads an appropriate quotation, talks about the group of muskrats with his playfellows, spends an hour in the library, or listens to the explanations of the museum "teacher," who gladly answers his questions and tells him stories, matters but little so long as the effect of his visit is to enhance his love for the best things in life. Another privilege extended to schools is the free use of stuffed birds, boxes of insects, and other "loan material" distributed for classroom study.

The demand for the privileges of a children's museum may be seen from the readiness with which schools and individuals accept them. More than 125 schools, many of them remotely situated, send pupils and teachers to our museum. Six hundred and thirty-two (632) visits from teachers alone in search of definite information, were recorded in the school months of 1907, and for the same period the Children's Museum lectures attracted an attendance of 18,000. The average annual attendance for the past five years has exceeded 94,000 visitors. It would seem from these statistics that a children's museum, if not a life necessity, is indeed an unquestioned blessing to a great city like our own whose population is boxed in apartments or brownstone blocks of such vast extent as to place the country beyond the experience of many children.

The advantage of a cheerful, sunny, attractive museum, rich in natural objects artistically displayed, where children are sure to find a sympathetic welcome, where they are safe and happily and profitably occupied, is scarcely appreciated until we pause to consider the influence for good or evil of habits acquired in leisure hours — and of the demoralizing influence of crowded city streets and back alleys.

Many of our " boys " and " girls " who are now young men and women paid their first visits to the museum in company with their parents or the family nurse. Year by year they have returned to the museum attracted by new features of the work adapted to their growing intellectual needs.

Two years ago in response to an expressed demand from the boys the museum began a course of lectures in elementary physics and in connection therewith invited the boys to come to the museum on certain afternoons to experiment individually with pieces of apparatus that most interested them. The boys found the utmost pleasure in the liberty thus granted — they experimented, under the guidance of a member of the museum staff, they read library books in connection with their experiments and within a few months several of the boys had set up a wireless telegraph station. The original work of these boys would be a credit to any institution for they applied themselves regularly and diligently until they had learned to send and receive wireless messages, meanwhile the experience of placing the station and keeping it in working order had fitted them to take charge of other stations. Early this summer when the schools closed, three of these " boys " received offers of remunerative positions with one of the commercial companies to take charge of wireless stations on board of ocean-going steamships to the West Indies, Bermudas, Key West, and other places of interest along the Atlantic seaboard. One of the boys who had learned to collect and mount insects when he came to the museum as a primary school lad made a very creditable collection of tropical insects which he brought to the museum carefully preserved and labeled with interesting data.

In contrast to the achievements of these boys by a wise use of spare moments, we can but wonder what these hours would have counted for if there had been no museum, no books, and no sympathetic personality to offer an occasional useful suggestion.

It has been maintained by some that physics and electricity are subjects not germain to museum work and that a museum should remain loyal to its old purposes of collecting, preserving, classifying, and exhibiting objects of scientific value. While the original object of a museum should be kept in mind we must not lose sight of the fact that a children's museum calls for such modifications and adaptations of methods as will enable children to use it, and here we must remember that the keynote of childhood and youth is action. Any museum ignoring this principle of activity in children must fail to attract them. The Children's Museum does not attempt to make electricians of its boys, nor is its purpose to do the work of any school. Its object is rather to get as near to the tastes and interests of its little people as possible, and to offer such helps and opportunities as the schools and homes can not give. With that its mission ends, and the success or failure of its work will be proportioned to its skill in meeting individual needs.

About a year ago a small boy was discovered in our building leading his 11 year old blind brother by the hand and telling him as much as he could about the objects of especial interest. The eagerness with which this sightless lad drank in every descriptive sentence led the museum escort to ask him if he had ever "seen" a squirrel. "No," he said, "I never touched one, but I have heard stories about squirrels — they have long, bushy tails and eats nuts." The escort then placing a stuffed squirrel in his hand, gave him one of the happiest experiences of his life. To his book knowledge he could now add a real discovery. Nor did his experience at the museum end with the squirrel, his sense of touch taught him many other stuffed animals and birds, besides living frogs, lizards, and turtles. There were other museums in Greater New York and surely far more costly exhibits, but no museum had hitherto found time to give this blind visitor the special attention his infirmity made necessary. Repeated and prolonged visits demonstrated the sincerity of his statement that "he felt as though he had come into a new world with all these animals."

Every September, children returning from the country outings hasten to tell us of their holiday pleasures, not the least of which, is the deeper appreciation of the world of nature of which the museum has given them broader knowledge. Examples of the quickening and stimulating influences of the museum in individual cases could be multiplied indefinitely and to this could be added the appreciative testimony of parents and teachers, were it necessary *to prove by* argument its real value to the community.

But, happily, the day is passed when its excuse for existence is questioned, or when it is regarded as an extravagant investment, yielding small returns. On the contrary, the returns would warrant an increased expenditure and this seems to be a necessity of the near future.

The present Children's Museum has long since outgrown its quarters. Its exhibition halls, its lecture room, and its library are often so overcrowded with eager children as to defeat the objects of their visits.

The New York Legislature, however, has recently passed a bill authorizing the city to erect a new children's museum building at a cost not to exceed $175,000. With the improved equipment thus provided the Children's Museum would not only serve a larger number of children, but would also serve them more efficiently in proportion to expenditure.

Through publications from the German press we learn that certain educators in Berlin advocate a children's museum for that city. Meanwhile, in our own country, museums are beginning to feel the importance of giving more attention to the education of children.

Since the Children's Museum has demonstrated its worth to one community there is reason to expect that it will make its way into others and the variety of problems to be solved in adapting its work to new conditions offers one of the most attractive fields in modern education.

Section C — EARTH SCIENCE

STREET CAR EXCURSION TO POINTS OF PHYSIOGRAPHIC FEATURES OF THE ITHACA REGION

LED BY OSCAR D. VON ENGELN, CORNELL UNIVERSITY

Board special car at Cornell University Library at 2 p. m.

Stop no. 1 Beebe lake bridge. Amphitheater and gorge succession in stream courses. Cause of the widening at the lake, and the gorges above and below. Other instances in Six Mile creek and bearing of these on theory of two glacial periods.

Stop no. 2 Fossil deltas of Cornell Heights. Tne glacial ice dam and its northward recession. The lake stages. Evidence of marginal channels (south hill) and old shore lines of their existence. Coy glen succession of deltas.

Stop no. 3 The ice eroded Cayuga valley. Double slope of the valley. Its overdeepened condition (423 feet to bottom, surface 381 feet above sea level). Joint plane and wind direction influences on cliff foundation. Dip of rocks.

Stop no. 4 Fall creek falls hanging valleys. Cause of numerous waterfalls. Variation of waterfall form. Joint plain development here and at Taughannock. Falls over the Tully limestone of Niagara type dissection of fossil deltas.

Stop no. 4 Renwick park. The delta plain. Levelness. Structure of plain. Artesian well conditions. Upbuilding of plain. Outbuilding of plain. Limit of plain under lake. Steep front 45 feet to 139 feet, 1¼ miles out. Position of side deltas with reference to wind direction.

Stop no. 6 Library Slope. Location of Ithaca. Comparison with Watkins. Alluvial fans. Position of inlet. Control of topography on transportation. Early history. Salt industry. Gypsum. Early geological conditions in this region.

Inspection of Geological Laboratories.

Friday evening, December 27

ELECTRICAL OSCILLATIONS

(Abstract)

BY J. S. SHEARER, CORNELL UNIVERSITY

The part which oscillatory changes play in modern physics has been only partially appreciated although of increasing importance during recent years. The simplest phenomena of this type is shown in the vibration of a strip of thin metal or wood clamped in a vise and carrying an adjustable load.

The type of vibration is determined by the shape and nature of the strip and its frequency by its rigidity or elastic return force and by the amount and distribution of the load.

Increase of elastic return force raises the frequency and decrease of load or placing it so that its inertia is less effective will act in the same way. We have in the knowledge of this fact the key to the control of such a vibratory system by regulation of these two quantities. Note that this mechanical vibration requires the expenditure of work in order to start it, the inertia of the mass carrying it past the equilibrium position. After the first supply of energy only enough need be given to supply the friction loss, in this case, a rather small amount.

In the mechanical case we see a moving mass and by reason of the muscular force exerted in starting it we realize in a vague way the variable force action involved. When, however, we deal with the electrical form of energy we can see no moving mass, we do not control the system by direct muscular force action and thus may fail to grasp the situation without recourse to some mechanical analogy.

For convenience let us suppose that electricity does consist of two unlike kinds of material of some intangible form and that equal parts of these two sorts are present in the normal state of all ordinary masses. Assume further that when one of these which we call + is in some way separated from the one called — there is set up a tendency to return to the original condition. Any electrical machine, cell, battery or dynamo is then a device for the separation of these + and — quantities and the work they do is stored in the form of electrical potential energy so long as the charges are kept separate. If the physical conditions are properly arranged the rush of charge when opportunity for readjustment is offered in part reverses the distribution of + and —, in other words sets up an oscillation of electricity analogous to the oscillation of mass.

In this case also there are two factors by means of which control may be secured as to frequency although the number of oscillations per second is almost incredibly large. One of these is the electrical capacity of the circuit which determines the amount of charge involved when the potential is fixed, and the other relates to the difficulty experienced when an electric current is started or stopped, in other words, to the self-induction of the circuit. Expressed in symbols the frequency depends on the $\sqrt{\ }$ LC where C is capacity and L is self-induction. When two circuits are so built up that the product LC is the same in each they are said to be in "tune." And oscillations set up in one will cause less vigorous electrical vibrations in the other. The effect of tuning was shown by several simple experiments illustrating the effect of change in each factor L and C.

Saturday morning, December 28

Section A — PHYSICS AND CHEMISTRY

THE STUDY OF SCIENCE BY YOUNG PEOPLE

BY WILLIAM S. FRANKLIN, LEHIGH UNIVERSITY, SOUTH BETHLEHEM, PA.

The philosophy of the 17th century for us of the 20th! Indeed I would have it so for my present purpose at least, and I ask you to adopt with me the intensely practical philosophy of that remarkable man of the world, Francis Bacon, who declared that "The real and legitimate goal of the sciences is the endowment of human life with new inventions and riches." Bacon's philosophy, which is a naïve admixture of insight and confusion, certainly stands for this idea, the service of science to mankind; and yet the scientific work of the 16th century, from which he drew his inspiration, pertained to realms very remote indeed from the doings of men. But now, after an era of scientific activity which is unprecedented in the history of the world, and which moreover relates to the things that all men use and to the things that all men do, what limit can be set to Bacon's kind of philosophy? At any rate it pretends to a conquering destiny. "We advise all men," says Bacon, "to think of the true ends of knowledge, and that they endeavor not after it for curiosity, contention, or the sake of despising others, nor yet for reputation, power, or any other such inferior consideration, but solely for the occasions and uses of life."

In his striking essay on the *Advancement of Learning,* Bacon surveys the coast of what, in view of the then recent developments of science, he is pleased to call "The new intellectual world," and before proceeding with what he apparently considers his greatest constructive effort, the *Novum Organum,* which is but dimly intelligible after the mutations of 300 years, he enumerates in his quaint way the deficiencies of knowledge in his time, and among other deficiencies he mentions "The Traditive Lamp, or the proper method of delivering down the sciences to posterity." The physical sciences, however, in their intimate human significance, are but newly created, and it is for us now to raise the question as to the proper method of delivering them down to posterity, and it seems to me that the greatest deficiency of knowledge in the realm of the physical sciences today is still that which was pointed out in semiprophecy by Bacon 300 years ago as the "Traditive Lamp."

My object in this paper is to establish a point of view from which we may consider in a broad and practical way the problem of "delivering the sciences down to posterity." The discussion will contain much that is light and common, but "We, who know that no judgment can be formed of that which is rare or remarkable without a previous regular examination of that which is common, are necessarily compelled to admit the most common objects into our discussion. Besides we have observed that nothing has been so injurious to philosophy as this circumstance, namely, that familiar and frequent objects do not arrest and detain man's contemplation, but are carelessly admitted, and their causes never inquired after; so that information on unknown subjects is not so much needed as attention to those which are known." [1]

Before proceeding with my main argument I wish to traverse a portion of a lecture[2] I gave several years ago to the older scholars of the Bethlehem schools in the attempt to justify in the minds of my young friends the coercion which is so prominent in modern technical and scientific education. In this lecture I endeavored to draw a sharp contrast between what may perhaps be called the normal activities of boys, and the activities that are involved in the rational study of the physical sciences, and I must let my words stand in their original form as addressed to the young people themselves in order not to eliminate a personal element without which the contrast vanishes.

Science, as young people study it, has two chief aspects, or, in other words, it may be roughly divided into two parts, namely, the study of those things which come upon us, as it were, and the study of those things which we deliberately devise. The things which come upon us include weather phenomena and every aspect and phase of the natural world, the things we can not escape; and the things we devise relate chiefly to the serious work of the world, the things we laboriously build and the things we deliberately and patiently seek.

You are, of course, familiar with the accepted division of science into biology, the science of plants and animals, and physics, the science of machines (what is a telescope, a test tube, or a still but a machine?). To a certain extent this corresponds to the division of science above mentioned, but, strictly speaking, the division of science into biology and physics has little to do with the distinction between the things that come upon us and the things we devise, and yet it is necessary for my present purpose to divide science on the basis of something which stands out clearly and distinctly in your eager souls so as to leave in every minute fraction as much as possible of the vital qualities which give pleasure or exact pains. Let us, therefore, divide nature on the basis of work and play; on the basis of painstaking and deliberate contriving on the one hand, and on the other hand of spontaneous and irresponsible joy.

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[1] *Novum Organum*, bk I, § CXIX.

[2] *The first of* a series of simple experimental lectures on physics.

In this mention of both work and play you may think that I am trying unfairly to catch your attention by alluding to the one thing you like above all others. Indeed, the things I shall ask you to consider during the winter are much more closely connected with work than with play, for the things we know best in physics today have to do with railways and ships and factories, and the things in physics which are most worthy to be known by every one are precisely these things which relate to the world's work.

On account of the remote connection between physics and play, and because of the great predominance in physics of the things which have to do with work, I am inclined to spend a portion of this, our first hour, free from the constraint that work implies, and to consider for a while the school of play, and that great school and playhouse, the Land of Out of Doors.

The friendly cow all red and white
  I love with all my heart;
She gives me milk with all her might,
  To eat with apple tart.

She wanders lowing here and there
  And yet she can not stray
All in the pleasant open air
  The glorious light of day.

To you, my young friends, everything is, I know, a joyful out of doors, and there you can not stray, all in the pleasant open air, the glorious light of day. To your fresh enthusiasm pretty nearly everything is play, and knowing no offense you accept, at par, ever aspect and phase of life, men, machinery and the enduring hills. I caution you to retain as you grow older as much as you can of this wide, and let us call it, matter-of-fact tolerance. Accept men and learn kindness and pity, accept machinery and learn dominion, and keep undefiled the sunlit hills and learn delight in life.

The Land of Out of Doors! What irony there is in such glowing phrase to city boys like yourselves! The supreme delight of my own boyhood days was to gather wild flowers in a wooded glen to reach which led across a sunny stretch of wild meadow rising to the sky, and I would have you know that I lived as a boy in a land where a weed never grew![1] Next to this delight in wild flowers and their haunts, my greatest delight was to watch the workings of a great sawmill, to see men play, as it seemed to me, eyes following every motion, ears filled with sounds like music in their sufficiency, heart leaping at every kind attention. A favorite uncle worked there for my father, the happiest man I ever knew, and since those early days I have learned but little about machinery, not much worth knowing about men, and nothing at all about meadowed hills!

When I was a boy I believe I would have walked almost any distance to see the inside of a turbine water wheel or to see one of those, even in my boyhood, old style and out of date water wheels which stand in picturesque decay in nearly every locality in these eastern states. I wonder how many of you have seen either kind, or even know that both kinds can be seen, inside and out, in our own neighborhood. Water wheels are perhaps a small and insignificant matter, too insignificant to warrant a trip to Easton[2] it may be, but what of the unparalleled opportunity which

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[1] The western prairies, except in the very center of the Mississippi valley, are beautifully rolling, and they meet every stream with deeply carved bluffs. In the early days every stream was fringed with woods; and prairie and woodland, alike, knew nothing beyond the evenly balanced contest of indigenous life; and then there came a succession of strange epidemics as one after another of our noxious weeds gained foothold in that fertile land. I remember well several years when dog-fennel grew in every nook and corner of my home town in Kansas; then after a few years a variety of thistle grew to the exclusion of every other uncultivated thing; and then followed a curious epidemic of tumble-weed, a low spreading annual which broke off at the ground in the fall and was rolled across the open country in countless millions by the autumn winds. I remember well my first lone "beggar louse" and how pretty I thought it was! And my first dandelion, and of that I have never changed my opinion!

[2] The lecturer had a few days previously taken several small boy friends to Easton to see a large water wheel which was being repaired. The superintendent of the plant put on overalls and went with us into the interior of the large boilerlike casing where we could see and touch the vital parts of the wheel. After the boys had examined the wheel, one of them perched himself on the topmost part in the dimly lighted interior and said, forgetful of the superintendent's kindness, "Pshaw, this isn't worth coming from *Bethlehem* to see!"

Bethlehem boys have amid the varied industries of the Lehigh valley! Do you care nothing to know about these things? or do you imagine that they are too complicated for you? Whatever you think, you must run them yourselves 20 years hence, or starve.

I wish that all youngsters might have access to the places where the wild flowers grow and have wide opportunity to see their fathers at work. A hundred years ago these things were really within the reach of every boy and girl, but now, alas, many a bright boy has seen no other manual labor than the digging of a ditch in a cluttered street, while many another, stunted in skill, has almost become a part of the machine he daily tends, and Boyville has become a paved and guttered city, high-walled, desolate, and dirty; with here and there a vacant lot hideous with refuse in early spring and overwhelmed with an increasing pestilence of weeds as the summer days go by, and the strangest thing about it all is the much too matter-of-fact tolerance among young people which accepts unquestioningly, and even with manifestations of joy, just any sort of a world if only it is flooded with sunshine.

I remember how in my own boyhood the rare advent of an old tin can in my favorite swimming hole used to offend me, while such a thing as a cast-off shoe was simply intolerable, and I do not wonder that the unquenchable delight of boys in out-of-door life becomes an absolute rage in its indifference to the dreadful pollution of the streams and to the universal pestilence of weeds and refuse in our thickly populated districts. I can not refrain from quoting an amusing poem of James Whitcomb Riley's which expresses, more completely than anything I know, the delight of boys in out-of-door life where so many things happen and so many things lure, and you can easily catch in the swing of Riley's verse that wanton note which is ordinarily so fascinatingly boyish but which may too easily turn to a raging indifference to everything that makes for purity in this troubled life of ours.

THREE JOLLY HUNTERS

O there were three jolly youngsters;
And a-hunting they did go,
With a setter-dog and a pointer-dog
And a yaller-dog also.
Looky there!

And they hunted and they hal-looed;
And the first thing they did find
Was a dingling-dangling hornet's-nest
A-swinging in the wind.
Looky there!

And the first one said "What is it?"
Said the next, "Let's punch and see,"
And the third one said, a mile from there,
"I wish we'd let it be."
Looky there! (Showing the back of his neck).

And they hunted and they hal-looed.
And the next thing they did raise
Was a brown bunnie cotton-tail
That vanished from their gaze
Looky there!

One said it was a hot base-ball,
Zipped thru the brambly thatch,
But the others said 'twas a note by post,
Or a telegraph-dispatch.
Looky there!

So they hunted and they hal-looed;
And the next thing they did sight,
Was a great big bull-dog chasing them,
And a farmer hollering "Skite!"
Looky there!

And the first one said "Hi-jinktum!"
And the next "Hi-jinktum-jee!"
And the last one said, "Them very words
Has just occurred to me!"
Looky there! (Showing the tattered seat of his pants).

This kind of hunting is, I assure you, better than the kind that needs a gun, and to one who falls into the habit of it, the gun is indeed a useless tool. I remember a day I spent with a gun in a remote part of the Rocky mountains where, during the 25 days I have camped there on four different trips, I have seen as many as 150 of the wildest of animals, the Rocky mountain sheep, being almost run over once by a group of five. On the day in question I became so interested in killing mosquitoes — I timed myself at intervals while I lay in ambush, 80 per minute for three hours making an honest estimate of 14,400 — I became so interested, I say, that the sheep came, and were out of range again before I saw them, and I was hungry too. I fancy they were not frightened but wished the good work to go on undisturbed.

Ich ging im Walde
So fuer mich hin
Und nichts zu suchen
Das war mein Sinn.

What I have chiefly in mind, however, in speaking to you of that great school of the Land of Out of Doors is what is nowadays called nature study. Do any of you like candy? Did you ever consider that the only sweetmeat our forefathers had for long thousands of years was wild honey? And those sour times — if I may call them such — before the days of sugar and candy, come much nearer to us than many of you realize, for I can remember my own grandfather's tales of bee hunting in Tennessee. Just imagine how exciting it must have been in the days of long ago to find a tree loaded with candy! A bee tree! If any one of you were to go back with me to the wild woods of Tennessee, some thrill of that old excitement would well up from the depths of your soul at finding such a tree, even if you were the son of Huyler or a nephew of the sugar trust. You may wonder what I am driving at, so I will tell you, that one of the most exciting experiences of my boyhood days was a battle with a colony of bumblebees. I was led into it by an older companion and the ardor and excitement of that battle, as I even now remember it, are wholly inexplicable to me except I think of it as a representation through inherited instinct of a 10 thousand years' search for wild honey.

It is my firm belief that nature study, as the natural boy knows it, grows out of the play of emotions and activities which constitute instinctive reactions toward natural things, hunting and fishing, digging and planting in the spring, nutting in the fall, and the thousands of variations which these things involve, and I believe that the play of instinct is the only solid basis of growth of a boy. I believe, furthermore, that the very essence of boy humor is bound up with the amazing incongruity of his instincts. Have any of you ever fooled a dog by placing him on a false scent, his instinct leading him astray? It is not easy to do, but done, it is mighty funny, and any decent dog enjoys the joke. Was there ever a boy whose instincts, many of them mere fatuity like his digestive appendix, have not led him time and again into just thin air, to say nothing of water and mud! For my part I have never known anything more supremely funny than learning what a hopeless mess of wood pulp[1] and worms a bumblebee's nest really is, except, perhaps seeing another boy learn the same stinging lesson.

The use of formulas, too, is unquestionably instinctive, and we all know how apt a boy is to indulge in formulas of the hocuspocus sort, like Tom Sawyer's recipe for removing warts by the combined charm of black midnight and a black cat, dead; and a boy arrives only late in his boyhood, if ever, to some sense of the distinction between formulas of this kind and such as are vital and rational. I think that there is much instruction and a great deal of humor connected with the play of this instinctive tendency. I remember a great big boy, a hired man on my grandfather's farm, in fact, who was led into a fight with a nest of hornets with the expectation that he would bear a charmed skin if he shouted in loud repetition the words " Jew's-harp, jew's-harp."

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[1] The "honeycomb" of the bumblebee is made of the paperlike material which wasps build their nests of, and every cell is filled with a big fat grub! No honey there! My friend Prof. H. S. Carhart assures me, however, that he has had better luck than I — in the end.

To reproduce for the city boy something approaching the solid reality and exquisite humor of the country boy's life is the well-nigh hopeless function of what our school teachers call nature study and of one class of children stories. Many storybooks are devoid of this vital element of humor, however, in that they relate too much to the complete and finished deeds of grown-up men. Robinson Crusoe, for example, never appealed very strongly to me, and, I think, for this reason Mr T. B. Aldrich's *Story of a Bad Boy* is, I am sure, a much better book.

I think you will agree with me that nature study is a complicated and elusive thing to be fully achieved only in the green school of the Land of Out of Doors; to young people the best playhouse, and to older people an endless asylum of delight.

The grass so little has to do,
A sphere of simple green
With only butterflies to brood
And bees to entertain.

And stir all day to pretty tunes
The breezes fetch along
And hold the sunshine in its lap
And — bow to everything.

And thread the dew all night, like pearls.
And make itself so fine,
A duchess were too common
For such a noticing.

And even when it dies, to pass
In odors so divine
As lowly spices gone to sleep
Or amulets of pine.

And then to dwell in sovereign barns
And dream the days away
The grass so little has to do —
I wish I were the hay.

All of you have, no doubt, followed what I have said concerning nature study with some degree of understanding, or at least with some degree of amused interest, and, I assure you, that I do not insist on the distinction between these two points of view. I am quite as well satisfied with the one as with the other in dealing with nature study in which the element of humor is so much more vital than the element of reason, but in undertaking to express my views of the study of the physical sciences, I shall be subject to severe limitations in the mode of my appeal to you, for here the element of humor is entirely lacking and reason alone prevails.

The study of the physical sciences does not depend upon the play of instinct to anything like the extent that nature study does, and you all realize that, while the elemental study of physics which consists in the visiting of mills and factories may be interesting to any boy, it is, nevertheless, devoid of the peculiar delight that all boys find in hunting and fishing. This elemental study, the seeing and handling of things, is not, however, the same thing as the study of physics in school. The study of the elementary physical sciences in school is, or should be, imaginative like the study of geometry, the object being to build up in the mind of the student a structure of notions and ideas on the basis of which he may be able to see into things.

Another aspect of the difference between nature study and the study of the elementary physical sciences relates to the newness of the physical sciences as a phase of human activity, whereas nature study, the kind I have told you about, is as old as the race. This nature study is really a recapitulation in the growing child of the entire history of the race, while the study of physical science, except in its rudiments, is a training which is to a great extent devoid of recapitulative elements.

What I wish to say to you, however, concerning the change in your mode of thought which must take place before you are fully entered into the life which modern science has prepared for you, may best be expressed by referring to the life history of a remarkable little animal, the axolotl, a kind of salamander, which lives a tadpolelike youth and never changes to the adult form unless a stress of dry weather annihilates his watery world; but he lives always and reproduces his kind as a tadpole, and a very funny looking tadpole he is, with his lungs hanging from the sides of his head as two great feathery tassels, brownish in tint, from the red blood inside and the mud that settles on the outside of the tiny tube-like streamers. I caught[1] one of these curious creatures when I was a boy and caged it in an aquarium, and I was greatly interested years afterward to learn more about it and to be told that it is a very rare animal indeed in my native state although plentiful enough in Mexico. When the aquatic home of the axolotl dries up he quickly develops a pair of internal lungs, lops off his tassels, and embarks on a new mode of life on land.

If you, my young friends, are ever to develop beyond the tadpole stage and become complete men according to the fullest present day significance of this term, you must meet, with quick and responsive inward growth that new and increasing stress of dryness as many men are wont to call our modern age of science and industry.

The best way, however, to characterize the study of physics is to take a concrete example. With this object in view, let us discuss briefly Newton's laws of motion. The most prominent aspect of all phenomena is motion. In that realm of nature which is not of man's devising motion is universal; ripple of brook, and gentle flow of river, ocean's swell and slow recurrent tide, and over all, incessant gusts of wind infinitely varied. In the other realm of nature, the realm of things devised, motion is no less prominent. Every purpose of our practical life is accomplished by movements of the body and by directed movements of tools and mechanisms, such as the swing of scythe and flail, and those studied movements of planer and lathe from which are evolved strong arm of steam shovel and deft fingers of the loom.

The laws of motion! You, my young friends, must have in some measure my own youthful view, which, to tell the truth, I have never wholly lost, that there is something absurd in the idea of reducing the more complicated phenomena of nature to an orderly system of mechanical law. For, to speak of motion is no doubt to call to your minds first of all the phenomena that are associated with the excessively complicated, incessantly changing, turbulent and tumbling motion of wind and water. These phenomena have always had the most insistent appeal to us, they have confronted us everywhere and always, and life is an unending contest with their fortuitous diversity which rises only too often to irresistible sweeps of destruction in fire and flood, and in calamitous crash of collision and collapse where all things mingle in one dread, fluid confusion.[1]

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[1] Speaking of catching things reminds the writer of a catfish he once saw gasping for air in water that had been muddied by the opening of a sluiceway in a dam. The boy swam up behind the fish, jambed a hand into each gill, and pushed the fish ashore; and it weighed 36 pounds! Once the writer, rowing around a sharp bend in a stream, saw a sandhill crane stalking along the shore; into the water went the boy, with the suddenly conceived idea that he could catch that crane, and, swimming low, he reached the shore about 20 feet from the bird, jumped quickly out of the water, made a sudden dash, and the bird was captured! A friend of the writer named Stebbins once followed his dog in a chase after a jack rabbit. The rabbit made a wide circle and came back to its own trail some distance ahead of the dog, made a sidewise jump, and sat looking at the dog as it passed by, so intently indeed that Stebbins walked up behind the rabbit and caught it with his hands.

The laws of motion! When I was a boy I read many scientific books with great interest, but I never could quite reconcile myself to a certain arrogant suggestion of completeness and universality. The laws of motion! My young friends, the science of mechanics is circumscribed in utter repudiation of such universal phrase; and yet curiously enough the ideas which constitute the laws of motion have an almost unlimited extent of legitimate range, and these ideas must be possessed with a complete precision if one is to acquire any solid knowledge whatever of the phenomena of motion, especially in the realm of devices which so serviceably accomplish the purposes of the human will, for in this realm, at least, everything is really and adequately correlated in a closely woven fabric of reason.

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[1] "The subtlety of Nature is far beyond that of sense or of the understanding; so that the specious meditations, speculations and theories of mankind are but a kind of insanity" [Novum Organum, bk I, § X].

There is at the present time a general awakening in philosophy and many scientific men seem to think that the world-wide talk on pragmatism is simply the first, long-delayed response of the great mass of men to the compelling philosophy of the experimental sciences, but it seems to the writer that this is by no means a complete diagnosis of the situation because some of the most striking features of the present philosophical movement are to be found in the transformation or reversion which the philosophy of the exact sciences is now undergoing. A period of remarkable activity in the physical sciences has been followed by a revolution in the conduct of business and industry, impressing the methods of the physical sciences upon great numbers of men, and the reciprocal effect is a growing domination of the exact sciences by a spirit of humanism, as pragmatism has been called in England. Indeed the changes which human interests as a whole are creating in the philosophy of the exact sciences are no less profound and significant than the changes which the physical sciences have brought about in the conditions of human life.

The change which is taking place in the philosophy of the exact sciences is many sided, but a prominent feature of it is the passing away of an old point of view, namely, that nature is exact and unvarying, that the so called laws of the physical sciences are ultimate realities, and that great simple facts of the physical universe are revealed in their perfection, one after another, to the divining spirit of mankind. It is not easy, however, to characterize the point of view which is now becoming dominant. In one way it may be described as a reenthronement of sense, and it may be exemplified by contrasting the introductory articles on hydraulics in Franklin and MacNutt's *Elements of Mechanics*, pages 218–25, with the point of view of the author of one of our best modern engineering treatises on hydraulics as indicated by the following extract: "Galileo said in 1630 that the laws *controlling* the motion of the planets in their celestial orbits were better understood than those *governing* the motion of water on the surface of the earth. This is true today, for *the theory of the flow of water in pipes and channels has not yet been perfected.*" [Italics ours] No! and it never will be Perfected! It would take too long to explain here just what is meant by this declaration for indeed it has nothing to do with the fool idea, if indeed it can be called an idea, that "the finite can not comprehend the infinite" so that "we may not presume to point out all the ways in which a God of unbounded resources might govern the universe." From such inanity may the great God of little things deliver us!

Every student should realize two things in connection with the study of the physical sciences. The first is that the study of the physical sciences is exacting beyond all compromise, and the second is that the completest science stands abashed before the infinitely complicated array of phenomena of the material world except only in the assurance which its method gives.

The necessity of precise ideas. Herein lies the impossibility of compromise in the teaching of the physical sciences and the necessity of constraint; one must think so and so, there is no other way. And the realm of precise ideas, that is the region I intended to symbolize by the land whereon the little Mexican tadpole, the axolotl, is forced to live by unwelcome stress of weather. I remember as a boy a sharp contest in my own mind between an extremely vivid sense of things physical and the constraining function of precise ideas. This contest is perennial, and it is by no means a one-sided contest between mere crudity and refinement, for refinement ignores many things. Indeed, precise ideas not only help to form our sense of the world in which we live, but they inhibit sense as well, and their rigid and unchallenged rule would be indeed a stress of dryness.

The laws of motion! I return again and yet again to the subject, for indeed I am not to be deterred therefrom by any concession of inadequacy, no, or by any degree of realization of the vividness of your youthful sense of those things which, to suit my narrow purpose, must be stripped completely bare. It is unfortunate however for my purpose that the prevailing type of motion, the flowing of water and the blowing of wind are useless as a basis for the establishment of the simple and precise ideas which are called the laws of motion and which are the most important of the fundamental principles of physics. These ideas have in fact grown out of the study of the simple phenomena which are associated with the motion of bodies in bulk, without perceptible change of form, the motion of rigid bodies, so called; and these ideas are limited in their strict application to these simple phenomena.

Before narrowing down the scope of my discussion, however, let me illustrate a very general application of the simplest idea of motion, the idea of velocity. You all have, no doubt, an idea of what is meant by the velocity of the wind, and a sailor, having what he calls a 10 knot wind, knows that he can manage his boat with a certain spread of canvas and that he can accomplish a certain portion of his voyage in a given time; but an experienced sailor, although he speaks glibly of a 10 knot wind, belies his speech by taking wise precaution against every conceivable emergency. He knows that a 10 knot wind is by no means a sure or a simple thing, with its incessant blasts and whirls; and a sensitive anemometer, having more regard for minutiae than any sailor, usually registers in every wind a number of almost complete but excessively irregular stops and starts every minute, and variations of direction that sweep round half the horizon!

We must, as you see, direct our attention to something simpler than the wind. Let us therefore consider the drawing of a wagon or the propulsion of a boat. It is a familiar experience that effort is required to start a body moving, and that continued effort is required to maintain the motion. Certain very simple facts as to the nature of this effort, as to the amount of effort required to produce motion, and as to the conditions determining the amount of effort required to keep a body in motion were discovered by Sir Isaac Newton and these facts are called the laws of motion.

The effort required to start a body or to keep it moving is called force. Thus if I start a box sliding along a table, I am said to exert a force on the box. I might accomplish the same effect by interposing a stick between my hand and the box, in which case I would exert a force on the stick and the stick in its turn would effect a force on the box. We thus arrive at the notion of force action between inanimate bodies, between the stick and the box in this case, and Newton pointed out that the force action between two bodies A and B always consists of two equal and opposite forces. That is to say, if body A exerts a force on B, then B exerts an equal and opposite force on A, or, to use Newton's words, "Action is equal to reaction and in a contrary direction."

I might have led up to a statement of this fact by considering the force with which I push on the box and the equal and opposite force with which the box pushes back on me, but if I do not wish to introduce the stick as an intermediary, it is much better to speak of the force with which my hand pushes on the box and the equal and opposite force with which the box pushes back on my hand, because, in discussing physical things, it is of the utmost importance to eliminate the personal element. I do not think that I shall find a better opportunity to explain to you further what I mean by the reference I have made to the curious life history of the little Mexican salamander, the axolotl. It is that our modern industrial life, in bringing men face to face with an entirely unprecedented array of intricate mechanical and physical problems, demands of every one a great and increasing amount of dry, impersonal thinking, and that the precise and rigorous modes of thought of the modern physical sciences are being forced upon widening circles of men with a relentless insistence which must soon give them complete and universal dominion in those realms of thought which have to do with the harder and more exacting aspects of man's relations to physical things.

When we examine into the conditions under which a body starts to move and the conditions under which a body once started is kept in motion, we shall come across a very remarkable fact, if we are careful to consider every force which acts upon the body, and this remarkable fact is that the forces which act upon a body which remains at rest are related to each other in precisely the same way as the forces which act upon a body which continues to move steadily along a straight path. Therefore, it is convenient to consider, first the relation between the forces which act upon a body at rest, or upon a body in uniform motion, and then to consider the relation between the forces which act upon a body which is starting or stopping or changing the direction of its motion.

Suppose one of you were to hold a box in mid-air. To do so it would be necessary for you to push up on the box so as to balance the downward pull of the earth, the weight of the box as we call it. Furthermore, if I were to take hold of the box and pull it in any direction, you would have to exert an equal pull on the box in the opposite direction to keep the box stationary. That is to say, the forces which act upon a stationary body are always balanced.

Every one, perhaps, realizes that what I have said about the balanced relation of the forces which act upon a stationary box, is equally true of the forces which act on a box similarly held in a steadily moving car or boat. Therefore, the forces which act upon a body which moves steadily along a straight path are balanced.

This is evidently true, as I have pointed out, when the moving body is surrounded on all sides by things which are moving along with it, as a car or a boat; but how about a body which moves *steadily* in a straight path but which is surrounded by bodies which do not move along with it? You know that some active agent such as a horse or a steam engine must pull steadily upon such a body to keep it in motion, and you know that if left to itself such a moving body quickly comes to rest. No doubt you have reached this further inference from your experience that this tendency of moving bodies to come to rest is due to the dragging forces, or friction, with which surrounding bodies act upon a body in motion. Thus a moving boat is brought to rest by the drag of the water when the propelling force ceases to act; a train of cars is brought to rest because of the drag due to friction when the pull of the locomotive ceases; a box which is moved across a table quickly comes to rest when left to itself, because of the drag due to friction between the box and the table.

We must, therefore, always consider two distinct forces when we are concerned with a body which is kept in motion, namely, the propelling force due to some active agent such as a horse or an engine, and the dragging force due to surrounding bodies. Newton pointed out that when a body is moving steadily along a straight path, the propelling force is always equal and opposite to the dragging force. Therefore the forces which act upon a body which is stationary, or which is moving uniformly along a straight path, are balanced forces.

I imagine that you will hesitate to accept as a fact the complete and exact balance of propelling and dragging forces on a body which is moving steadily along a straight path in the open. All I can say is that direct experiment shows it to be true, and that the most elaborate calculations and inferences based upon this notion of the complete balance of propelling and dragging forces on a body in uniform motion are verified by experiment. You may ask, why should a canal boat, for example, continue to move if the pull of the mule does not exceed the drag of the water; but why should it stop if the drag does not exceed the pull? You understand that we are not considering the starting of the boat. The fact is that the conscious effort which one must exert even to drive a mule, the cost of the mule, and the expense of his keep, are what most people think of, however hard one tries to direct their attention solely to the state of tension of the rope that hitches the mule to the boat after the boat is in full motion; and most people come upon the idea that if the function of the mule is simply to balance the drag of the water so as to keep the boat from stopping, then why should there not be some way to avoid the cost of so insignificant an operation? There is, indeed, an extremely important matter involved here which we will consider when we come to the discussion of work and energy; but it has no bearing on the matter of the balance of propulsion and drag on a body which moves steadily along a straight path.

Let us now consider the relation between the forces which act upon a body which is changing its speed, upon a body which is being started or stopped, for example. I suppose that you have noticed how a mule strains at his rope when starting a canal boat, especially if the boat is heavily loaded, and how the boat continues to move for a long time after the mule ceases to pull. In the first case, the pull of the mule greatly exceeds the drag of the water, and the speed of the boat increases; and in the second case, the drag of the water exceeds the pull of the mule, for the mule is not pulling at all, and the speed of the boat decreases. When the speed of a body is changing, the forces which act on the body are unbalanced; we may conclude that the effect of an unbalanced force acting on a body is to change the velocity of the body; and it is evident that the longer the unbalanced force continues to act the greater the change of velocity. Thus if the mule ceases to pull on a canal boat for one second, the velocity of the boat will be but slightly reduced by the unbalanced drag of the water, whereas if the mule ceases to pull for two seconds the decrease of velocity will be much greater. In fact the change of velocity due to a given unbalanced force is proportional to the time that the force continues to act. This is exemplified by a body falling under the action of the unbalanced pull of the earth; after one second it will have gained a certain amount of velocity (about 32 feet per second), after two seconds it will have made a total gain of twice as much velocity (about 64 feet per second) and so on. Furthermore, since the velocity produced by an unbalanced force is proportional to the time that the force continues to act, it is evident that the effect of the force should be specified as so much velocity produced per second, exactly as in the case of earning money; the amount one earns is proportional to the length of time that one continues to work, and we always specify one's earning capacity as so much money earned per day.

Every one knows what it means to give an easy pull or a hard pull on a body. That is to say, we all have the ideas of greater or less as applied to forces. Everybody knows also that if a mule pulls hard at a canal boat, the boat will get under way more quickly than if the pull is easy, that is, the boat will gain more velocity per unit of time under the action of a hard pull than under the action of an easy pull. Therefore, any precise statement of the effect of an unbalanced force on a given body must correlate the precise value of the force and the exact amount of velocity produced per unit of time by the force. This seems a very difficult thing, but its apparent difficulty is very largely due to the fact that as yet we have not agreed as to what we are to understand by the statement that one force is precisely three, or four, or any number of times as great as another. Suppose, therefore, that we agree to call one force twice as large as another when it will produce in a given body twice as much velocity in a given time (remembering of course that we are now talking about unbalanced forces, or that we are assuming for the sake of simplicity of statement that no dragging forces exist). As a result of this definition we may state that the amount of velocity produced per second in a given body by an unbalanced force is proportional to the force.

Of course we know no more about the matter in hand than we did before we adopted the definition, but we do have a good illustration of how important a part is played in the study of science by what we may call making up one's mind, in the sense of putting one's mind in order. This kind of thing is very prominent in the study of elementary physics, and by that rather indefinite reference, in my story of the little tasseled salamander to an inward growth so needful to you before you can hope for any measure of success in our modern world of scientific industry, I meant to refer to this thing, the "making up" of one's mind. Nothing is so essential in the acquirement of exact and solid knowledge as the possession of precise ideas, not indeed that a perfect precision is necessary as a means for retaining knowledge but that nothing else so effectually opens the mind for the perception even of the simplest evidences of a subject. Opens the mind, that is, for those things which are conformable to or consistent with the ideas. The history of science presents many cases in which accepted ideas have closed the mind to contrary evidences for many generations. Let young men beware![1]

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[1] This ends the abstract from the lecture to the older scholars of the Bethlehem schools.

The study of physical science considered as a transformation of the mind

To teach the physical sciences effectively is, I believe, to completely transform the mind of a young man, and I think that this transformation is a reorganization of the rich materials of the primitive mind of a boy. Every one is, of course, familiar with the life history of a butterfly, how it lives at first as a caterpillar and then undergoes a complete transformation into a winged insect. It is of course evident that the bodily organs of the caterpillar are not at all suited to the needs of the butterfly, the very food (of those species which take food) being entirely different. As a matter of fact, almost every portion of the bodily structure of the butterfly is dissolved, as it were, into a formless pulp at the beginning of the transformation, and the organization of a flying insect then grows out from a central nucleus very much as a chicken grows in the food stuff of an egg. So it is in the development of the modern mind. In early childhood, if the individual has been favored by fortune, he exercises and develops more or less extensively the primitive instincts and modes of the race in a free, outdoor life, and the result is so much mind stuff to be dissolved and transformed with more or less coercion and under more or less constraint into an effective mind of the 20th century type.

Nothing is more completely established in psychology nowadays than that ideas can not be formed out of the clear sky, as it were. They must be built of stuff, and the rational study of the physical sciences especially in its earlier stages is the transformation of simple intimate knowledge into general ideas. All elemental knowledge, such as the knowing how to throw a ball, how to ride a bicycle, how to swim, or how to use a tool, is locked in the marginal region of the mind (the region of reflexes) as a very substantial but very highly specialized kind of intuition, and the problem of the teaching of elementary physical science is the problem of how, by verbal and concrete suggestion, to drag this material into the field of consciousness[1] where it may be transformed into a generalized logical structure having traffic relations with every department of the mind. An abstract treatment of the principles of elementary physics, tends more than anything else, to inhibit the influx of this elemental knowledge from the marginal regions into the field of consciousness and results in the building up of a theoretical structure which can have no effectual traffic with any mental field beyond its own narrow boundaries. Such a state of mind is nothing but a kind of idiocy, and to call it a knowledge of elementary science is weak scholasticism.

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[1] The writer has had an experience in these matters which, he believes, is very unusual. Every attempt he has ever made to develop muscular skill, as in playing ball or tennis, has seemed to be disturbed by a sort of meddling consciousness. He remembers the attempt made in 1875 to learn manual telegraphy, in which a brother and a sister became expert, whereas his own sending was always spasmodic and uncertain in character, and never for a moment free; and the same has always been true of his ball and tennis playing. But the instincts of a fish! These seem to be deeply seated indeed, for the writer has never seen the person to whom he would eld in the matter of swimming!

There are in my opinion two chief errors prevalent among teachars of the physical sciences, an error of assumption and an error of perversion, and I will explain each in terms of an example. A short time ago a friend of mine, in speaking of his method of discussing the subject of sliding friction in class, said that he placed on the blackboard a sketch of a block resting on a moderately smooth plane and then asked the class to consider the force necessary to move it up or down. Now, I have found it possible to use, in class discussion, a student's experience of a severe jerk when he boards a rapidly moving car, his experience of the great effort required at the starting of a heavy boat, his experience of the steady pull required to keep a boat in motion, and many other elemental experiences of this kind; but I have found that the utterly confused experiences which every man has as to the opposing forces which act upon solid bodies when starting or when in motion, make it impossible to bring a simple case like the above into the mind of the student by any amount of verbal suggestion. I believe that any discussion of the approximate laws of friction between moderately smooth bodies must be based upon an actual experiment by the student carried out under the very simple conditions as specified. The very simple experience which it is desired to use in this case is hopelessly involved among the infinitely complicated and variable experiences which men have as to the obstruction of motion or solid bodies. It is a serious mistake in the teaching of elementary physical sciences to assume a specialized form of experience on the part of the student. Elemental experience exists in superabundance, specialized experience is rare.

Some time ago an incident occurred in the classroom of one of our best teachers of mathematics who is charged also with the teaching of elementary mechanics. The subject of projectiles being up for discussion, a rather stupid student was called sharply to account with the question, "What is a projectile, anyway?"

"Would you be a projectile if I were to pitch you out of the window?" "Yes," replied the young man hesitatingly, and he was met with the instant response "No, you wouldn't. A projectile is a material particle." Now, a material particle is nothing but an idea, and it stands for our agreement with ourselves to consider only the translatory motion of the body we are studying. It is very desirable indeed to express ideas in objective terms as if the ideas existed physically, thus we speak of the material particle, of the rigid body, of the perfectly elastic solid, of the frictionless incompressible fluid, of the perfect gas, of the atom, of the molecule, and so on. Helmholtz says, indeed, that "It is a great advantage for the sure understanding of all abstractions if one seeks to make the most concrete possible pictures of them." The use of objective terms in speaking of abstractions, however, is apt to bring about that confusion of boundaries between our logical structures and the objective realms of reality, which, according to Münsterberg, is the gravest danger of our time, and there can be no doubt but that one of the greatest errors in the teaching of the elementary physical sciences is precisely this confusion of boundaries. Ideas must be recognized as ideas, and their application must not be totally inhibited by our thinking of them as the things to which they themselves apply. The idea of a material particle is applicable to any material system, however complicated, however turbulent, for, in fact, we may, if we choose, direct our attention to the translatory motion of such a system. If one were to twirl a wriggling eel in a circular path at the end of a length of fish line, one would find the idea of a material particle useful in describing certain aspects of the motion, although the behavior of an eel under the pushing and pulling efforts of a fisherman to disengage it from the hook, does, I admit, transcend the idea of a material particle.

"Our method," says Bacon, "is continually to dwell among things soberly, without abstracting or setting the mind further from them than makes their images meet," and, "the capital precept for the whole undertaking is that the eye of the mind be never taken off from things themselves, but receive their images as they truly are, and God forbid that we should offer the dreams of fancy for a model of the world."

In order that I may be able to specify in a general way what it is that is to be built up in the mind of a young man by the rational study of the physical sciences, let me distinguish two chief results of the scientific activity of the last half century, namely, (1) an accumulated mass of fact, under which heading I would include all of the details of applied science, for indeed the most important and compelling facts that have been accumulated by the sciences are the facts which are incorporated in the settled doings of men; and (2) an established mode of thought and inquiry which may be designated, using a suggestive phrase of Bacon's, as "A new engine, or a help to the mind corresponding to tools for the hand."

We continually force upon the extremely meager data obtained directly through our senses an interpretation which in its complexity and penetration would seem to be entirely incommensurate[1] with the data themselves, and we exercise over physical things a kind of rational control which transcends the native cunning of the hand. The possibility of this forced interpretation and of this rational control depends upon the use of two complexes, (*a*) a logical structure, that is to say, a body of mathematical and conceptual theory which is brought to bear upon the immediate materials of sense, and (*b*) a mechanical structure, that is to say, either (1) a carefully planned arrangement of apparatus such as is always used in making measurements, or (2) a carefully planned order of operations such as the successive operations of solution, reaction, precipitation, filtration and weighing in chemistry.

These two complexes do indeed constitute a " new engine " which helps the mind as tools help the hand; it is through the operation of this engine that the interpretations and control of the physical sciences are made possible; and the study of elementary physics is intended to lead to the realization of this new engine (1) by building up in the mind the logical structure of the physical sciences, (2) by training in the making of measurements and especially in the performance of ordered operations, and (3) by exercises in the application of these things to the actual phenomena of physics and chemistry at every step and all the time with every possible variation.

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[1] For example an astronomer listens to the beats of a clock as he watches a spot of light move across the field of a transit circle, noting the time of transit across the middle cross hair, and then he notes the reading of the divided circle. This he does three times in succession, and from this data he determines the orbit of the spot of light (a comet) around the sun, predicting when it will come nearest to the sun and how far away it will be, when it will return, and so on. The chemist can see the color of a solution or precipitate and he can perceive its odor and taste, and above all he can weigh it, but he can not do much besides, and any one who is familiar with the results of organic chemistry, as represented in the modern benzene theory for instance, must realize that they are little short of marvelous. The recent work of Rutherford and others on radioactivity, again, is based on what would seem to be an absurdly slender group of observable effects.

The process of building up the logical structure of the physical sciences is very largely the rehabilitation of the sensuous elements of the mind in relations which are continuously new. The possibility of this process has grown up as a human faculty almost solely on the basis of language. Definite parts of the sensuous content of the mind become fixedly associated with definite words, and the reapplication of old words on the sliding scales of similitude and analogy, rehabilitates the old materials of the mind in ever widening relations. But a large part of simple theoretical physics is constructed out of sensuous elements which are not habitually and fixedly associated with verbal forms of expression, and it is impossible to marshal these elements in any other way than by direct appeal, by sight or feeling, to the actual things which correspond to them. I refer here to the purely mechanical aspects of elementary physics, and to the degree to which a mechanical sense forms the basis of the logical structure of the whole of physics and chemistry. Most men seem to imagine indeed that a physical theory is a vague sort of analogy between strongly anthropomorphic ideas and hazy generalities of things, but the fact is that a physical theory comes very near indeed to being a mechanical model or a machine. The molecular theory in chemistry, for example, is as truly a mechanism as a locomotive, except that a locomotive must be actually constructed to be used, whereas the molecular theory need only be imagined. Let no one suppose, however, that it is as easy to imagine the molecular theory as it is to build a locomotive!

The notion seems to be widely prevalent that the logical structure of the physical sciences is a structure of mathematical functions and formulas; but geometrical and especially mechanical ideas and conceptions completely dominate the physical sciences from beginning to end. Arithmetic, including algebra and calculus, is important in working from given data to numerical results, but the argument is in every case mechanical or geometrical, and without geometrical and mechanical ideas physical theory becomes absolutely sterile. Mathematics to most people means numbers, and the lack of appreciation, in many quarters, of the tremendous importance of geometry and mechanics — the picture book of the physical sciences which is too little perused — seems to be due to the fact that the idea of number, of all impersonal ideas, has obtained by far the strongest hold on the human mind. Deeply ingrained in every human being is the feeling that number relates to actual things, fish, or beads, or cattle, or dollars, and to my mind the most remarkable fact connected with the teaching of the physical sciences is that it is so very easy to cheat young people into the belief that a study relates to something real if it involves arithmetic. I believe indeed that one of the most serious perversions in the teaching of the elementary and advanced physical sciences is that which is involved in the assignment of great numbers of problems which are more or less completely detached from actual physical things or which involve data the determination of which is not within the range of the student's knowledge or experience. " Natural philosophy is not yet to be found unadulterated, but is impure and corrupted . . . by mathematics, which ought rather to terminate natural philosophy than to generate or create it." [Novum Organum, bk I, § XCVI]

Concerning a course in physics for the secondary school

The most important thing, I should say, for the successful teaching of physics in the secondary school is that ample opportunity be given for every variety of play, including swimming and skating, and, wherever possible, boating. It is ridiculous to attempt to teach physics, or anything else for that matter, without the substantial results of play to build upon. Playgrounds are the cheapest and in many respects the best of schools, but alas they are almost entirely lacking in many of our towns which have grown to cities in a generation in this great " Nation of Villagers." The boroughs of Bethlehem, for example, (for we have a kind of virtue in not pretending to be a city), have no playground connected with a public school, nor any other public place where boys can play ball.

WHAT DO YOU THINK?[1]

We, the editors, have been dragged along back alleys, across open sewers, and through rank growths of weed and thistle to view the Monocacy meadows to consider the possibility of their use as a playground or park. We are not much impressed with the proposal, the place is apparently hopeless, but the park enthusiasts could not be touched by argument. To our very practical objection that the cost would be excessive he made the foolish reply that there is no cost but a saving in using what has hitherto been wasted. To our expressed disgust for the open sewers and filth he replied that that was beside the question, for, as he said, we must sooner or later take care of the filth anyway. But, we said, the creek is contaminated above the town,[2] very well, he replied, we have the right to prohibit such contamination. And worst of all, in double meaning, was his instant agreement to our statement that we had our cemeteries which, he said, were really better than any Bethlehem park could be.

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[1] This and the following communication are from a small paper, printed and published by two Bethlehem boys.

[2] There are in fact several water mills above the town, and any one who knows the secrets of a small water mill knows what that means!

COMMUNICATION

Dear Editors: I took a walk along the Monocacy creek on Sunday after noon and discovered clear water several miles above town and a fine skating pond; but I suppose that you and all of your subscribers will have to go to our enterprising neighbor, Allentown, to find any well kept ice to skate on this winter. Most people think that you boys can swim in nature's own water, skate on nature's own ice, and roam in nature's own woods, but it is absolutely certain that your elders must take some care and pains if you town boys are to do any of these things, and yet, here in the East, children are said to be brought up (implying care and pains) and hogs are said to be raised (implying only feeding). I thank the Lord that I was "raised" in the West where there are no such false distinctions.

Your subscriber S.

P. S. As I came home covered with beggar-lice and cockle burrs, I saw a ring of fire on South mountain, an annual occurrence which has been delayed a whole week this autumn by a flourish of posters in several languages offering One Hundred Dollars Reward!

S.

Knowing my interest in parks and playgrounds, the local editor of a real, steam engine newspaper asked me kindly to write him a communication, and, not knowing how to do so formal a thing, I sent him the following which he considerately published with the exception of the last sentence.

To the Editor of ———

What can be charged against a community like the Bethlehems as more indicative of that dreadful carelessness, the common neglect of children, than that there is no fit place for our boys to swim? Oh yes, there is one really fine place, as I know from experience, and there is nothing I would like so much to do as to turn Pied Piper and lure the entire brood of Bethlehem boys and girls to Friedensville[1] and into that awful chasm of crystal water to come back no more, no, not even when an awakened civic consciousness (my! how some people do like that word!) had made a park of the beautiful Monocacy meadows and converted the creek into a chain, a regular Diamond Necklace of swimming holes. I beg the garbage men's (*not* a printer's error for man's) pardon for speaking of the beautiful Monocacy meadows. I refer to what has been and to

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The peaceful site of an abandoned zinc mine where sheer walls of rock *round a three*-acre pool of perfectly clear cool water, hundreds of feet *epth.*

what might easily continue to be. As for the Diamond Necklace, that of course would have to be above the Gas Works where the small stream of *pure* tar now joins the main stream.

There, Mr Editor, is your communication.

S.

It seems utterly foolish to talk of teaching elementary physics (for I must stick to my subject) to boys who live in towns like Bethlehem, and yet we are no worse than some of the neighboring villages, Philadelphia and New York, for instance! We boast of having conquered nature; well, we have now got to domesticate the wild thing before much else can be done in this country of ours! We have got to do it, and it is foolish to talk of teaching physics, to people who fail to realize this fact. I suppose that I am as familiar with the requirements of modern industry as any man living and as ready to tolerate everything that is economically wise, but every day as I walk to and fro I see the Monocacy creek covered with a scum of tar, and in crossing the river bridge I see a half mile long heap of rotting refuse serving the Lehigh as a bank on the southern side; not all furnace refuse either by any means, but nameless stinking stuff cast off by an indifferent population and carelessly left in its very midst in one long unprecedented panorama of putrescent ugliness! And when on splendid autumn days the near-by slopes of old South Mountain lift the eyes into pure oblivion of these distressing things, I see anon a line of fire sweeping through the scanty woods. This I have seen every autumn since first I came to Bethlehem.

It is easy to speak in amusing hyperbole of garbage heaps and of brooks befouled with tar, but to have seen one futile flourish of posters on South Mountain in eleven years! that is beyond any possible touch of humor. It is indeed unfortunate that our river is not fit for boys to swim in, and it is not, for I have tried it, and I am not fastidious either, having lived an amphibious boyhood on the banks of the muddiest river in the world; but it is a positive disgrace that it is not fit to look at,[1] that it is good for nothing whatever but to drink, much too good, one would think, for people who protect the only stretch of woodland that is accessible to their boys and girls by a mere flourish of posters!

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[1] At the end of one of our main bridges is a hotel with an omnibus chute behind, and there it stands, a brazen paralized brute, heaping its dung forever!

Wh—a—a—t I h-h-ave said concerning the complete transformation of the mind of a boy by science study, refers to the final result after school and college, and of course the character of the elementary science instruction in the secondary school is not to be determined wholly by such philosophy as I have attempted to set forth. Transformation means the change of something into something else, not the making of something out of nothing; and what this original something is and how to get hold of it so as to change it into something else are no less important than a clear idea of what you wish to convert the original thing into. How is the science teacher to get hold of the primitive mind of a boy? That is the question. And you will please understand that in considering this question I have not the least desire to relieve the boy from coercion. It is not a question of ease and pleasure but solely a question of effectiveness.

In the past the scientist in his capacity as teacher, has had to assume the role of magician to a greater or less extent.

When old Sir Henry Wotton was sent as ambassador "to *lie* abroad" (as he wittily called it, to his cost) in a piece of business relating to a brief Bohemian kingship that was fated soon to explode at the battle of Weissenberg in 1620, he saw at the city of Lintz, in the picturesque green country by the shores of the Danube, there, an ingenious person who is now recognizable as one of the remarkablest of mankind, Mr John Kepler, namely: Keplar as Wotton writes him, addressing the great Lord Bacon on that among other subjects. Mr John's now ever memorable watching of the motions of the planet Mars with "calculations repeated seventy times," and his discovery of the planetary laws of this universe some ten years before appear to be unknown to Wotton; but there is something else of Mr John's devising which deserves the attention of the Instaurator[1] of Philosophy: "He hath a little black tent" says the ambassador, "which he can suddenly set up where he will in a field; and it is convertible (like a windmill) to all quarters at pleasure; capable of not much more than one man, as I can see, and perhaps at no great ease; exactly close and dark, save at one hole about an inch and a half in diameter to which he applies a long perspective trunk with the convex glass fitted to the said hole, and the concave taken out at the other end, which extendeth to about the middle of this erected tent: through which the visible radiations of all the objects without are intromitted, falling upon a paper, which is accommodated to receive them; and so he traceth them with his pen in their natural appearance, turning his little tent round by degrees until he hath designed the whole aspect of the field." In fact, he hath a *camera obscura* and is exhibiting the same for the delectation of imperial gentlemen lounging that way. Mr John invents such toys, writes almanacs, practices medicine, for good reasons, his encouragement from the Holy Roman Empire and mankind being only a pension of 18 pounds a year, and that hardly ever paid. An ingenious person truly, if there ever was one among Adam's posterity. Just turned of 50 and badly-off for cash.

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[1] Bacon himself called his *Advancement of Learning* and his *Novum Organum*, his Great Instauration, hence Carlyle's reference to him as the Instaurator of Philosophy.

The temper of the world, however, is fast becoming such that there is no need of nor even toleration for the magic element in science. Every one is beginning to recognize the tremendous importance of the physical sciences in everyday life, and it is now possible for a teacher of the elementary physical sciences to devote himself to a homely study of the things which are more or less familiar to every boy. The possibility of this kind of elementary science study is perhaps the most important fact to be reckoned with in connection with the teaching of the elementary physical sciences in the secondary school, but there is still a very serious difficulty which I can explain with the help of an example. A few weeks ago I gave an experimental lecture at a distance from Bethlehem. I was obliged to carry a delicate piece of apparatus with me in the train, and I was greatly amused when a fellow asked facetiously if I was carrying "a new-fangled contrapshun for catching chickens." A good-natured laugh satisfied the fellow, of course, but I could not help thinking that his question indicated about where I would have to begin to explain the thing to him. A great difficulty in the teaching of the physical sciences is that the human mind, intuitively habituated as it is to consider the immediate practical affairs of life, can hardly be turned to that minute consideration of apparently insignificant details which is so necessary in the scientific handling even of the most distinctly practical problems. I believe that this quality of detachment, which is an especially prominent feature of nearly every fundamental principle of physical science, must be seriously reckoned with in any attempt to formulate a practical course of instruction in elementary physics in the secondary school.

Some time ago I was talking with my own boy about his physical laboratory work in school, and I was greatly interested in his expression of contempt for a piece of work he had done, namely, the determination of the force required to break a wire. Just picture to yourselves how contemptible a teacher would be in the eyes of a wild Indian whom he had set at such work, and my boy is indeed a kind of a wild Indian. Suppose it does take so much force to break a wire, and suppose you do divide this force by the sectional area of the wire. What in the name of all that is real does it mean to a boy? But if you make use of this experimental result as a basis for enabling a boy to estimate the number of locomotives of one hundred tons each that could be supported by the Brooklyn bridge, and this particular problem is simple enough for any boy to handle, then the whole aspect of the matter would be changed, and the boy would begin to be differentiated from a genuine wild Indian. Suppose, however, that the teacher does not relate the experiment with the wire to some significant condition or thing, then most assuredly he would deserve the contempt that any boy would have for him, and if you know boys at all, you must know that capacity for contempt is one of their strong points.

It was Lord Kelvin, I believe, who made a statement many years ago to the effect that when we can measure a thing we know all about it, and it seems to me that the most widely approved high school course in elementary physics at the present day is in accord with a literal interpretation of this statement of Lord Kelvin's; but my experience is, most emphatically, that a student may measure a thing and know nothing at all about it, and I believe that the present high school courses in elementary physics in which quantitative laboratory work is so strongly emphasized are altogether bad. Quantitative laboratory work has pedagogical value in conjunction with classroom work which is devoted to the advanced mathematical theory of the physical sciences, but I believe that the only quantitative physical laboratory work that should be given in the secondary school is that which can be justified by the practical value of measurement in everyday life and business, and that which relates to things of which the boy has some intimate knowledge independently of what is brought to him by the laboratory work itself. Let a boy determine the velocity of a runner by observing the time required to run a measured distance; let the power that can be developed by a boy be determined by observing the time required for him to climb a measured flight of stairs (any healthy boy of 16 years can develop a horse power and a quarter); let a boy estimate the length of his normal walking step by counting the number of steps in a measured distance; let the area of a lot in acres be determined by stepping off its length and its breadth; let a boy estimate the value of a piece of timber by measuring its dimensions, knowing the cost per thousand board feet; let the velocity of water in a nozzle be calculated from the measured volume of discharge in a known interval of time and the measured diameter of the nozzle; let the pressure of gas in the city mains be determined by measuring the depression of water level in a glass tube connected to a gas cock; let the pressure of water in the laboratory supply pipes be estimated on the basis of Torricelli's theorem and the measured velocity at which the water issues from a small nozzle; if there is a canal near the school, let the boy measure approximately the velocity of the water in the canal by stepping off the distance traveled by a float in a known interval of time and then let him estimate the volume of water discharged per second by measuring the depth and width of the canal; let a boy determine the density of a variety of substances of regular geometrical form by weighing and measuring volumes; let him determine the specific gravity of wood by measuring the submerged length of a slim stick; let a boy determine rainfall by means of a simple rain gauge and let him record atmospheric temperature, wind direction, and degree of cloudiness for a period of a month; and so on. In short, let a boy get his own data for a great variety of simple numerical problems in the solution of which he may be supposed to have some interest because of knowledge independent of that which comes to him in the making of the measurements.

I believe that the physical sciences should be taught in the secondary school with reference primarily to their practical applications. The textbook should be devoted chiefly to the description and analysis of the more familiar practical applications of physics accompanied by many illustrations of actual devices and processes, and the laboratory work should be of the character suggested above. Such a course would be of the greatest value to young men who do not enter college, and it would furnish a most satisfactory basis for college work in the physical sciences.

I have recently followed the work of my own boy in a good preparatory school and a short time ago I helped him to get the "answers" to a group of problems under Newton's law of universal gravitation. The problems related to the mass of the sun and moon and to the weight of a body at a distance of thousands of miles from the earth! I have examined hundreds of young men in elementary physics many of whom had had a great deal of quantitative laboratory work concerning things they knew little or nothing about. They could talk ohms, and volts, and amperes, and focal lengths and images, and candle power, and what not; but I have never seen much evidence of that growth of simple intimate knowledge into general ideas which is the very essence of what should be accomplished in the study of elementary physics. More than half of the boys I have examined have been unable to tell the specific gravity of a stick knowing that it floated three quarters submerged in water, and I think it is no exaggeration to say that less than ten per cent of the boys have been able to calculate the specific gravity of oil when told that a stick floats three quarters submerged in water and seven eighths submerged in oil. One question which I have used many times in my examinations refers to the scheme of connections and to the principle of continuous vibration of the ordinary electric bell, and from my experience with this question and others like it, I am led to believe that the study of physics in our secondary schools does not accomplish the one thing which it may be expected to accomplish in the less familiar branches of physics, namely, to furnish an intimate knowledge of some few of the phenomena, a knowledge which is surely necessary before any attempt can be made to develop the general ideas of these branches of physics. I think that the laboratory work in these less familiar branches should consist almost entirely of manipulations approaching shopwork in character.

I do not insist on the study of the practical things in physics merely because of their practical value, although I believe that this consideration alone should determine the trend of all general instruction in elementary physics and chemistry, but I can not endure a so called knowledge of elementary science which does not relate to some actual physical condition or thing, and I believe that the only physical things that are sufficiently prominent in a young man's mind to be brought into the field of his science study are the things which have been impressed upon him in everyday life. Say what you will, you must do one of two things to be able to teach physics in any school; either you must create an actual world of the unusual phenomena of nature by purchasing an elaborate and expensive equipment of scientific apparatus, or, you must make use of the boy's everyday world of actual conditions and things. One of these things must be done; there is no other way.

Section B — BIOLOGY.

THE EDUCATIONAL USES OF SHARKS AND RAYS, ESPECIALLY THE ACANTH (SQUALUS ACANTHIAS, "HORNED DOGFISH")

(Abstract)

BY BURT G. WILDER, CORNELL UNIVERSITY

Half a century ago students of vertebrate zoology and comparative anatomy dissected the human body and such animals as chance provided. During the last 30 years the desirability of selecting certain so called types or representatives of the several groups to be dissected in accordance with directions has become recognized. The choice of forms has varied greatly with localities, instructors and periods. Theoretic appropriateness and practical availability have sometimes conflicted.

As the outcome of 40 years of experience and reflection, and with increasing conviction as to the supreme importance of the early acquisition of some real knowledge of the brain, I submit the following proposition:

For the study of the structure, development, succession and relationships of vertebrates .the best group to begin with is the selachians, the sharks and rays; if several forms can be studied the first should be — and if but one, that one should be — the acanth or "horned dogfish," *Squalus acanthias.*

Some of the points involved in the foregoing proposition have been discussed by me in Wilder and Gage's *Anatomical Technology,* pages 56–57, 1882; *Methods of Studying the Brain,* Cartwright Lectures before the Alumni Association of the College of Physicians and Surgeons of New York, *New York Medical Journal,* February 9, 1884, page 147; "The Desirability and the Feasibility of the Acquisition of Some Real and Accurate Knowledge of the Brain by Precollegiate Pupils," *Science,* December 17, 1897, page 903; "The Brains of *Scymnus* etc., with Remarks upon Selachian Brains for Standpoints Morphic . . . and Pedagogic," read at the annual general meeting of the American Philosophical Society, April 1905, *Science,* May 26, page 814; and "The Educational Uses of Certain Vertebrates and of Certain Vertebrate Brains," read (by title) before the section in general zoology of the Seventh International Zoological Congress, Boston, August

1907. Acanths of various ages may be had from dealers, especially the Supply Department of the Marine Biological Laboratory at Woods Hole, Mass., and the Harpswell Laboratory of Tufts College, Mass. Directions for dissection have been published by Prof. J. S. Kingsley (Henry Holt & Co.,) and Prof. L. E. Griffin of the Missouri Valley College, Marshall, Mo. With slight differences there apply also the portions relating to the "dogfish" of Europe in the *Practical Zoology* by the Parker Brothers (Macmillan Co.,) and by Marshall and Hurst (G. P. Putnam's Sons). Since this paper was read I learn from Prof. W. A. Locy of Northwestern University, that his course in comparative anatomy begins with the acanth.

Besides its purely zoologic uses the acanth may facilitate the solution of an educational and moral problem the importance and difficulty of which are forcing themselves upon parents, teachers and sociologists.[1] The following is based upon my rough notes of a lecture by Prof. Louis Agassiz in November 1867, the ninth of a course of 21 lectures upon selachians. Later he said he had tried to state what he regarded as very important facts concerning a delicate subject in such a way as not to disturb the women among the audience.

Unlike most of the lower vertebrates, with many kinds of sharks and rays the young are developed within the mother and the two sexes are easily distinguished by outward form. With the male the inner margins of the pelvic fins are prolonged and modified so as to constitute organs by means of which, while facing the female, the seminal liquid is introduced and internal impregnation is accomplished. These fishes are among the earliest vertebrates, yet their sexual relations were prophetic of conditions among the higher classes, among the mammals, and even with the other extreme of the series, the human species.

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[1] Witness an article in *The Nature-Study Review* for November 1907, editorials in the *Ladies' Home Journal,* especially for January 1908, and the "Educational Pamphlets," 1-4, of the American Society for Sanitary and Moral Prophylaxis.

FIRST YEAR BIOLOGY IN NEW YORK CITY

BY ZILLAH HEIDENHEIM, CURTIS HIGH SCHOOL, STATEN ISLAND

You are all familiar with the requirements of the first year course in high school biology, embracing botany, zoology, and physiology as it is prescribed by the Board of Regents of the State of New York, and each has his convictions as to the conditions under which the work should be conducted and what its aim should be.

I desire to point out here, the conditions under which first year biology is taught in New York city, and to indicate briefly what the aim of the work conducted under these conditions must be.

Conditions. The first half of the year is devoted exclusively to botany, the second half to zoology and physiology. In some schools the second term is equally divided between the two latter subjects but in the majority the larger part of the time is devoted to zoology and only the necessary six weeks prescribed by the syllabus are given to physiology. In other schools, the human physiology and zoology are carried along together.

Each day is divided into six 45 minute periods. In most of the schools the biology teacher instructs during four of these, a fifth period is devoted to supervision in study hall or guard duty, leaving only one period free for preparation of the work. Sometimes this period is filled by assisting another in laboratory.

The size of classes varies with the locality of the school. Where the entering classes average five and six hundred the biology sections are of necessity very large, each class containing 35 or 40 pupils. A class of 18 or 20, which is as large as any biology class should be, is unheard of except in the smaller high schools of the city.

At present there is no high school which has not at least one good laboratory. Each of the newer schools is provided with several, well lighted and well arranged. One of these buildings in Brooklyn which is just about to open, contains five biology laboratories, each connected with a small room where all preparations are made. There is also an animal room and a conservatory in the building. It is intended that all the recitations shall be carried on in the laboratory, and practice may be substituted at any time for the recitation. This condition should exist in all the schools, and it is to be hoped that something may, in the course of time, be done to remedy the conditions existing in the older high schools, where the number of pupils is so great that the single well equipped laboratory is far from adequate. In one of our largest high schools the zoology laboratory exercises are conducted in a cellar where the light is so poor that except on the brightest days it is impossible to work without artificial lights. All laboratory work carried on outside of the double laboratory period necessitates the carrying about of materials from room to room. The teacher is obliged to distribute material, give a lesson and again collect the material within the 45 minutes. The most capable teacher and enthusiastic pupil are handicapped under such conditions.

Some of the schools have a double laboratory period of an hour and a half, although several schools have two of these double laboratory periods and one recitation. In schools where it is customary to have one double laboratory period another single period is devoted to laboratory practice. It seems to be the general custom however, to have two recitations, and three laboratory periods of 45 minutes each.

Microscope. The laboratories are provided with compound microscopes. In most of the schools these are used by the pupil, although the time spent in the use of the microscope by the individual pupil during the year, varies from two 45 minute periods in one school to a full five weeks in another. The use of the microscope is indispensable to a comprehension of animal or plant structure and physiology, but its use by the pupil in the first year of high school is unwise, since the time spent in mastering the methods of handling the instrument can be more profitably devoted to other work and essentials can be taught by demonstration.

In all the laboratories a combination of the investigation and verification method are used. The investigation method is of course the more predominant since it brings out more fully the disciplinary value of the work, emphasizes the scientific method and develops that self-confidence and independence of thought and action in the pupil which are indispensable to successful work of any kind.

Three methods of keeping laboratory notes and drawings are in vogue. The most popular is the slip sheet system. Notes and drawings are kept in a cover to which papers may be added or from which they may be withdrawn. This method seems the best as the books are of convenient size; the covers may be changed and poor work may be corrected and withdrawn. In other schools the drawings are kept in envelops and the notes in a bound book. The third method is that of pasting drawings in a book in which the notes have been written.

Supplies are furnished by dealers in the city. Those for use in class are fairly good but rarely arrive at the right time. The teacher can usually obtain all that are needed. It is the exceptional principal who cuts down the supplies for economy's sake. These supplies include living and prepared material for class work as well as prepared material for demonstration, glass ware, and other apparatus. Anything can be obtained by ordering, provided the teacher is in no hurry to use supplies that are not on the regular list. We have recently been requested to limit our expenditures to 30 cents per pupil for the year. Most of us will find some difficulty in meeting this request.

In the city where the classes are large and the schools at a distance from the country, the field work is limited. The parks, museums, and aquarium, in New York and Brooklyn are, however, much used.

Aim. "The first year course in biology is designed to give students a general conception of the wide range of forms in animal and plant life; to lead them to observe the various processes carried on by plants and animals, and to study only so much of structure as is necessary for a clear comprehension of these processes, and to help them understand the general structure of the human body and the way to care for it."

One can readily see that the purpose quoted above from the syllabus of first year biology for high schools allows of much diversity in specific aim. This specific aim varies with the viewpoint of the individual teacher and is sometimes determined by the attitude of the principal toward the work. In each school, however, there is unity of aim, secured by departmental meetings. At these meetings all important questions are decided and teachers are kept in touch with one another's work. One of the schools emphasizes the economic aspect of the work, another the physiologic aspect, dwelling particularly on the human physiology, some emphasize the great diversity and range of plant and animal form and structure, trying to make scientists of the children.

Of the pupils who enter our high schools less than 20 per cent graduate, the greatest falling off occurs in the first year. This defection is attributed to various causes. Chief among these is the pupils' attitude toward the work. They dislike it, they find it too difficult, they feel that their high school work has no practical bearing on life.

In view of such conditions the biology teacher must first secure the interest of the pupil, and second fill the course with those facts and ideas which have the closest relation to everyday life. Professor Bigelow has said, "In teaching the elements of biology, we have yet to learn concentration on important and fundamental principles and to spend less time upon details of which organisms present unlimited variety." There is a general tendency to devote too much time to giving the pupil a conception of the range of forms and structure in animal and plant life, instead of emphasizing the important life processes. It is of far greater importance that the pupil should thoroughly understand the structure of some one form, and the way in which its organs function, and for this study I would recommend the frog, than that he should be familiar with a representative of each branch of the animal kingdom.

Teachers of science are apt to talk over the heads of beginners, forgetting that heretofore their mental pabulum has been predigested and doled out in small quantities. We can not make scientists of these children. Huxley has said: "You must not be too solicitous to fill the pupil with information, but you must be careful that what he learns he knows of his own knowledge. Pursue this discipline carefully and conscientiously, and you will make sure that however scanty may be the measure of information which you have pounded into the boy's mind, you have created an intellectual habit of priceless value in practical life."

Pupils are usually interested in those things which are useful and which have a bearing upon their immediate life. There are two other means of securing interest, which are not emphasized as much as they should be. The historical side of biology is entirely neglected. Very few of our pupils know anything of Darwin, Huxley, Agassiz, Gray, to say nothing of the discovery of the blood and the germ theory of disease. A boy who knows the difficulties placed in the way of the scientist as a result of superstition, and the ingenious methods used by them in their work, will realize that these men have discovered a new kingdom, have conquered a world of facts, and will feel that interest in their science which they have in the work of any hero who overcomes difficulties. The second point which I believe holds the pupil to this subject is turning his attention to some one branch and inducing him to make collections of insects or flowers or encouraging him in studying birds. A successful appeal to the pupil along one of *these lines* may arouse a lifelong interest in the work, whatever *his vocation.*

Our second aim we said was to fill the course with those facts and ideas which have the closest relation to everyday life. We must lay stress upon the importance of agriculture, the extermination of pests, medical plants, some time should be given to the study of the handling of food products and raw materials for manufacture, to the study of disease and sanitation. We must emphasize the study of the relation of all forms of life to man, point out the similarity of processes performed by all animals. For the rest we should make the work center about the physiology, limiting if necessary the forms studied to those one or two which show what the structure of the human body is like — sacrifice extent to content.

Recently the authorities have requested the biology teachers to make the work more interesting, more descriptive, and to take up less of the intimate structure of forms. The request emphasizes, I think, what has before been said, the tendency of the biology teacher to devote too much time to range of form and structure. Since our pupils leave in such large numbers during their first year, and some knowledge of life processes is essential to all human beings, this work in biology should remain where it is in the high school course, but we must limit our work to the mere requirements of the syllabus, and the capacity of the pupil, we must be satisfied with giving the pupil a knowledge of the essential facts in regard to a limited number of forms, together with those additions which I have suggested, namely directing the pupil's attention to making collections, interesting him in the history of the science, and making the humanistic side of biology the basis of our work.

EXPERIMENTAL WORK IN BIOLOGY

BY CYRUS A. KING, ERASMUS HALL HIGH SCHOOL, BROOKLYN, N. Y.

Read in absence of author

All will agree, even our worst enemies — the teachers of the classics — that the study of biology gives the pupil both knowledge and mental training. It matters not how poorly the subject is taught, both these results follow. This, however, is about as definitely as the outsider usually sees the results of our course, for this is, in many instances, what he himself is seeking to give his pupils. To the teacher of biology, this is scarcely an introductory aim. He knows that biology has a definite and special place in the high school course because, if rightly taught, it appeals to the pupil in a special way.

Not only must our work give knowledge, but it must, as far as possible, give *first-hand* knowledge. The textbook, the great desideratum in his other first year subjects, is in biology relegated to its proper place in the background and the pupil is required to study the plants and animals themselves. In other words, if our subject justifies itself from our own standpoint, it must derive its chief value from the fact that it is the one subject in his first year that carries the pupil, in a degree, away from his books and makes him study the things themselves. It is necessary for the success of the course that all the biology teachers in the State should be a unity, both theoretically and practically, as to the above conception. For not until we all give our courses so as to bring the laboratory side of the work into prominence, shall we meet with the respectful recognition that the subject deserves. The writer is not so unsophisticated as to assume that he is stating to his hearers a new conception of the biology course. He believes that there is pretty general agreement that the laboratory work should receive emphasis.

Too often, however, we can not in practice come up to our theoretical ideas of what should be done in the course. Even in our larger high schools this is difficult; in the smaller schools of the State, the overworked teacher, who may be required to teach other subjects besides biology, and, in addition, do enough clerical work for one person, has still less time to give to the preparation of his laboratory work. On the other hand, if the biology teacher has a well equipped laboratory and wants to do the work in an approved way, he is confronted with a whole series of problems in working out a set of studies suited to the needs of his pupils.

To do the laboratory work well, the teacher must have thought through the course and adapted the studies of the various plant and animal forms used to the intellectual capacity of first year pupils. The course must give the pupils first-hand, definite information about some of the great biological processes that are going on in plants and animals. It must not degenerate into an elementary nature study course nor, neither in whole or in part, must it aim to prepare the pupil for a medical school.

As a result of all this pressure both from without and within, the teacher is often forced to follow the line of least resistance — to do that which requires the least energy and initiative — to substitute for laboratory work the study of the textbook, charts, and figures.

Whether or not the teacher takes time to do experimental work there is sufficient reason for using it at every available place if it visualizes the question to be considered and thus leads to clearness of conception; if the experiment is convincing when successfully carried out; if it develops originality and independence in the pupils who must think out, and in part, devise ways and means to do the experiment; and finally, if it gets a definite series of reactions from the pupils.

The writer has been doing experimental work in his botany classes during the past five years and regards it as an integral part of the work. Before requiring the pupils to do an experiment it is, in most cases, better, to discuss it in class. It must be clear that there is some question as to whether a certain organ really does perform a particular work; for example, the question as to whether or not the leaf gives off water vapor. After the question is stated to the class the teacher can then ask for suggestions as to how the pupils could prove whether or not leaves give off water vapor. If the question is too difficult for the pupils to answer at once, assign it for home work and have them write out additional suggestions for the next day. If the teacher can get the pupils to write out a series of statements that show how to prove the point, he has gotten a reaction from them, aroused interest, and excited their curiosity as to whether their respective theories of the way to prove the problem will work out in actual practice. Finally, as a result of this work, the pupils are better prepared to understand the experiment even though the teacher, in the end, performs it as a demonstration. In fact, some of the pupils will test their theories of the more simple experiments before bringing them into class to be discussed and criticised. The teacher should remember, therefore, that one of the most important features of the experimental work is the discussion as to how the problem may be solved. It is only in this way that a certain element in each class will actually find out what it is all about. Criticisms and objections to various suggested plans for an experiment will enable these pupils to grasp more clearly the real question to be tested as well as the best means of testing it. It is only after the problem to be tested is clear, and the ways and means of testing it are evident that some of the sluggish, lazy pupils are willing to take the initiative and try the experiment as home work. However, as the teacher carries on the work, he can, by questioning, stir up the indifferent pupils and get from them, too, suggestions as to the way in which new experiments may be done.

It has been the writer's experience that the first year high school pupils soon become good critics of the fairness and accuracy of an experiment. Furthermore, they are, in general, readily taught to be honest in this work. They soon see the value of an honest control experiment and many of them will insist on one before they are willing to accept the evidence as shown by the experiment. Then, too, they are quick to recognize defective experiments even in our textbooks; the practical worthlessness of a conclusion drawn from attempting to grow but two seedlings, one of which has been mutilated, has been frequently pointed out to me by my pupils. With a minimum of a dozen of each kind of seedling the practical results of the experiment are certain to be more accurate and to the pupil will seem fairer.

It is often a stimulus to the experimental home work to have the pupils bring the experiment and the control to school. For this work, the pupil should receive an official mark because he must be made to feel that he has done, or at least has attempted to do, an integral part of the course. If the teacher is in doubt as to the genuineness of these home experiments, one or two detailed questions will usually decide the matter. As a rule, the pupils can do only the more simple experiments at home. Of these, a full series of observations and notes should be made and, in many cases it is well to ask for illustrations also. Other experiments requiring more apparatus should be set up under the teacher's direction in class and the pupils required to make sketches and notes to show that they understand what the experiment teaches. Finally, some of the experiments are done more satisfactorily during the regular laboratory period. In these, too, the pupil must have a clear notion of the problem and of the reason for each step of the experiment. Otherwise many of the students will passively perform the experiment and not get its real significance.

We have found it a convenience for our pupils to arrange the experimental work into three classes, (*a*) laboratory work, (*b*) demonstrations, and (*c*) home work, with the understanding that the work in the first group is to be done by the individual pupils in the laboratory and is required of all; that the demonstrations are to be performed before the class by the teacher and by pupils with the teacher's help, and that these observations, notes and conclusions form a regular part of the work and are required of all pupils unless marked optional. Finally, it is understood that the home work experiments are required unless marked optional. The required home work must be written up in neat and logical form.

A simple device that has been of great practical service in the experimental plant work, particularly the home work, has been called for want of a better name a *pocket garden*. It is made in a variety of ways, but a very serviceable one may consist of two negatives, that have been cleaned, two pieces of black cloth the same size as the negatives and several pieces of blotting paper the size of the glass and cloth. After the seeds have been soaked, the pocket garden is made by putting the wet blotters together and the pieces of cloth on each side of them; the seeds, a half dozen or more are placed on the outside of each piece of cloth, and the glasses are put outside the seeds and fastened together at the two ends by means of string or elastic bands.

The pocket garden is now finished, and the student may watch through the glasses all the stages in germination of the various seeds which he has been asked to plant or cares to plant for himself. It is necessary to keep the interior moist, but if the garden is generously supplied with blotters it will maintain its moisture for several hours. We have had no difficulty whatever in keeping dozens of these gardens in the laboratory indefinitely by putting them on edge into a pan which contains some water. The black cloth is used because the parts of the young seedlings are usually white and the root hairs particularly, come out in sharp contrast on the black background.

These pocket gardens have been used in practically all the experimental work suggested in the State syllabus under seeds and seedlings, roots and stems, as well as in additional experiments not suggested by the syllabus.

To use a single illustration, suppose the pupil wants to find out whether or not the roots and stems of germinating seeds have a constant direction of growth with reference to gravity. Two gardens may be used and while one is kept in the same position the other may be shifted at all sorts of angles to see if there is any corresponding response in the direction of growth of the roots and stems of the half dozen young plants that are developing on each side of it. India ink marks on the glass may help to follow the migrating movements of these roots and stems.

The syllabus does not suggest experiments under flowers and fruits. It would, however, help to emphasize the function of the flower as a whole as well as of its stamens and pistils if the teacher should, as a demonstration, pollinate the flowers of a potted plant and compare the later development of these pistils with others like the Begonia, from which pollen has been excluded. If the pupils have already seen pollen under the microscope and have observed as a demonstration pollen tubes that have been germinated artificially, they are able to understand better the purpose of the pollen, of the stigma, and of fertilization with its bearing on seed production. Since the flower is usually studied chiefly for its taxonomic importance, it will be well to emphasize to the student its real purpose as well as the purpose of its parts.

In conclusion, too much attention can not be given to any work that will emphasize the fact that plants and animals are after all fundamentally alike; and that the same great biological processes are going on in both. For example, the pupil knows that digestion takes place within his own body, that he must be nourished, that he breathes by using up oxygen and giving off carbon dioxid, that there is a circulation of liquids going on within himself, that he is irritable and responds in definite ways to external stimuli and that his body is carrying on other vital processes, but it has never occurred to him that the same biological activities are going on in the plants about him.

While certain of these processes may be demonstrated more easily in plants and others in animals it should be shown as far as possible that they are all going on in both. We can not give our pupils any adequate idea of the real significance of these great principles if we do not emphasize them by experiment wherever there is an opportunity in the different forms studied. There are the important facts that make the year's course a unity and if they are brought out at every step, they are more certain to be understood at the end of the course.

Section C — EARTH SCIENCE

POWER QUESTIONS AND THEIR VALUE

BY JENNIE T. MARTIN, BUSINESS HIGH SCHOOL, WASHINGTON, D. C.

First, what do we mean by power questions? They are those which show how much mental food has been assimilated or how much intellectual muscle has been developed. In teaching physical geography I have had some experience with three classes of thought questions.

A Those whose answers depend upon known facts but which can not be found in textbooks.

B Those which are plausible in form but absurd in content.

C Original diagrams and maps to test knowledge of structure and development of physiographic features and the power of visualizing on the part of the pupil.

I will illustrate each of the three classes by actual questions and problems which I have used.

Under practical questions are the following:

1 Give the process by which the mica schist along Rock creek is being changed to clay.

2 Which is more useful for water power, the Potomac at Washington or Rock creek (a stream of high gradient) and why?

3 Why are the pebbles in the gravel beds about Washington, round and hard? What do they show about the origin of the beds?

4 What are the uses of the Potomac to the people of Washington?

5 Why is the clay of New York State better for crops than the clay of Virginia?

6 Why does the asphalt pavement sometimes bulge in summer? Why are so many repairs necessary in the spring?

Illustrating absurd questions are the following:

1 Why is the soil in the Mississippi flood plains about Cairo finer than it is at New Orleans?

2 Explain fully why so many volcanoes are found in the interior of Asia.

3 Why are caves commonly found in sandstone?

4 If a cyclonic storm center is at Buffalo, December 5, how many days later will it reach St Paul, Minn.?

5 Why is the weather so warm at the center of an anticyclone area?

The following list of test diagrams suggests their character.

1 Draw 5 diagrams illustrating as many stages in the development of a river valley.

2 Draw 5 diagrams illustrating the successive changes in the divide between two rivers that develop from youth to old age.

3 Draw 5 stages in the formation of a cavern.

4 Draw a map of a hill drained by five rivers. (Use shading, hachures or contours).

Draw:

1 A cavern containing an underground stream.
2 A later stage of the same showing a natural bridge.
3 A view of number "2" as seen from above.

To make such questions most stimulating and valuable, they should be used both in recitations and written tests. The absurd questions should be introduced among reasonable ones with no hint of their character, and they should not be overworked. Practical questions applying principles can not be too frequently used. One of the most important uses of the test diagram is to reveal to the teacher the state of the pupils' minds, and the revelation is often wonderful indeed.

Saturday afternoon, December 28

THE PURIFICATION OF WATER

(Abstract)

BY E. M. CHAMOT, CORNELL UNIVERSITY

The increasing complexity of modern life involving as it does the massing of population in certain districts and the wholesale distribution of water and food has served to intensify many difficulties in sanitation.

Nowhere is this more marked than in the question of water supply on account of the prevalence and nature of water-borne diseases. It has, in fact, become impossible to supply most municipalities with water from any natural source which is or may not become at any moment a source of danger from typhoid or other enteric disorders.

With this fact established it has been found necessary to resort to some process for the removal of bacteria or their destruction. Two general methods of filtration to accomplish this removal have come into use and are known as the slow or sand filtration and the mechanical or American method. The first of these requires large sand beds which are scraped periodically and on which there forms the so called pathogenic layer which is the active agent. The second method employs a coagulant which forms a glutinous mass and on settling carries the bacteria with it. After settling, the clearer portion is filtered through small sand beds, which may be washed by reverse flow.

There is no marked difference in efficiency in these two types of filter. When properly constructed and operated the removal of organisms is practically complete and the water is entirely safe.

Many illustrations of filter plants and their methods of operation were given and also statistics on the cost to the community of water-borne diseases and how water becames polluted. It was made clear that water purification has become an economic question of prime importance as well as a sanitary one.

THE TEACHING OF SCIENCE

(Abstract)

BY L. H. BAILEY

It is first necessary to state what science is. It is fact, organized. It consists of indisputable knowledge and accepted rational hypothesis.

Organized fact underlies all effective living, and therefore all civilization that is worthy of the name. We have largely passed through the theological interpretation of the natural world; we have also passed through the philosophical interpretation of it; we are now in the epoch of the scientific interpretation, which is to ascertain the fundamental facts in respect to it and to reason only therefrom.

We are teachers; it is our business to open the minds of the young to the methods, the points of view, and the facts of science.

It is first of all essential that we distinguish between the teaching function and the research function. The research function is essential to the determination of the ultimate fact; but as teachers we are concerned primarily with the mode of presentation to the young minds. I propose to suggest four or five considerations that make for good teaching of science.

a Our minds must be open to the truth if we are to teach accurately and effectively. It is not the business of the teacher of science to prove a thesis, nor to assume gratuitously a point of view. In this respect the scientist differs from other men. It is a lawyer's business, for example, to advocate, or to prove a case and, therefore, to that extent he can not be a scientist. Neither are ministers scientists, for they start with an assumption of what truth is and then make their investigation fit the hypothesis. When ministers really become scientists, religion, as we now formulate it, will be upset but we shall arrive thereby at a truer statement of religion and a better outlook on life. Philosophers usually are not scientists because they start with an assumed premise. They are very likely to deceive themselves in the end. In the past they have too often been sophists. The scientist is interested in his fact and bases everything thereon; the philosopher and minister are likely to be interested more in the process of the argument or interpretation. The real scientist is absolutely impartial to himself and to his work. No matter what opinions he may have expressed, or what books he may have written in support of any line of thought, he at once disregards his former position if he finds that facts are against it; and he is as intensely interested to discover these facts as any other person would be. Very few persons really desire to know the truth, and there are very few that are willing to believe it, even though they may be all unconscious of this mental attitude. So thoroughly are tradition, preconceptions and prejudices established in us that it is very difficult for any man so completely to dissociate himself that he can interpret the natural world without coloring his interpretation by his own personality. I suppose that we can never dissociate the interpretation of nature from personality; but the nearer the approach to this state the truer will be our outlook toward fact.

All these statements are well illustrated in the general movement of thought consequent on the publication of Darwin's books. Before his time the theological explanation of the world was dominant: animals and plants are what they are and where they are because so made and placed by the Creator. The adaptation of these organisms to their conditions is perfect because they were designed to be perfect. Darwin's philosophy challenged all this. The interpretation of nature following the publication of Darwin's early works, however, had just as strong teleological trend as before, for all the characteristics and organs of plants and animals were supposed to have been perfectly adapted to their conditions through long struggle for existence and survival of the fittest. It, therefore, became a habit of mind to ask what everything is for. Does a leaf have hairs, we assume that the hairs must have some definite purpose, even though they have arisen as the result of natural selection. Does the cactus have spines, they must be for the purpose of protecting the plant from browsing animals. Does an animal have curious markings, they must serve some purpose in its protection. The interpretation of nature was still definite. We have now learned, however, that we must not approach objects in nature with any assumption that everything serves a purpose. A few days ago a teacher wrote me asking what is the use of the peg on the germinating squash plant. I replied that I was not aware that it had any use; I am afraid that she was shocked when she got my letter. The proper attitude is not to ask what a thing is for, but to ask what it is.

b As science teachers we must put the learner into touch with life and activity. I am sure that we have been too much inclined to separate our teaching from the affairs of life. It has been a popular demand that education be "practical," but educators seem to have resisted the demand to a large extent. I think that we would be in danger of giving the student a partial view of science and of life if all our teaching were to be practical in the sense of being usable in securing dollars and cents, but it certainly must be true that the practical affairs of life are as well worth incorporating into a body of knowledge and method of training as any other affairs or facts are. It is equally partial to teach only those things which do not have relation to the affairs of life, which unfortunately has been common. I like to use the word "adaptable" or "applicable" in the place of "practical."

I do not at all like the division of subject-matter into pure science and other science for I do not like the implication that some science is impure. All science is science whether it has any direct or obvious application or not and it is all equally worth teaching; but when we are dealing with the young it should be our opportunity so to instruct and lead out as to put the pupil into direct and sympathetic relations with the life he is living. I know a junior in college, for example, who has had college physics; he knows practically nothing about light, or heat, or sound, or friction, or the common physical phenomena of life, although he has had much mathematics. I am quite sure that some of us really learned more of understandable and relevant physics from Wells's old *Natural Philosophy* than some persons now learn from a course in physics. In the old days we taught botany to a large extent by requiring the pupils to collect plants and to press them neatly between layers of paper. We have passed that epoch and we do not wish to return to it; and yet that method with all its shortcomings had the advantage of taking the pupil out of doors and putting him in touch with real plants. Then came the German laboratory method and the study of minute structure and training in technic. We gained much in dexterity and we got nearer the fundamental facts but we lost our touch with life. It is not true that it is best to begin the teaching of plants by discussion of the cell and the lower forms of flowerless plants and all that. The first course in botany should put the pupil into rational relationship with the plants about him in their larger and grosser phases. We have passed through a similar phase in the teaching of zoology and we are now in the epoch of teaching physiology formally and sometimes even partially. It is significant that there is now a demand for the teaching of biology whereby we are to get hold of the underlying processes of life whether in the plant, the animal or the human being, and we shall learn what are the reactions of all these organisms to their conditions and environments. This teaching will be what we ought to mean by the word practical.

c It is apparent that we are in the beginning of a widespread dissatisfaction with the textbook. This in fact amounts in some places to a revolt. This is one expression of the conviction that teaching should begin with the natural activities of the child and that books should be a secondary and incidental consideration. Every practical teacher, of course, recognizes that the textbook must be used, but we are beginning to feel that it is not a primary agent. The dissatisfaction is not so much with the textbook itself as with the character of the books. They have been developed very largely from the college or academic point of view and have been written too often by men engaged in college teaching. The colleges have imposed their methods on the schools. This method is usually too advanced in point of view for the public schools. It usually attempts to work out a body of knowledge rather than to put the pupil directly into relationship with the activities of life. The schools should now be strong enough to develop their own methods and their points of view even if in the end they thereby dominate the colleges.

The mere textbook teaching is nearly always poor teaching. Likewise the mere indoor laboratory teaching may be just as bad as exclusive textbook work. We have heard much about the poor teaching in the public schools. Speaking with public school teachers in mind, I bid them be comforted. Some of the poorest teaching I have ever seen has been in the colleges and universities. In the qualifications of the college teacher, the emphasis is likely to be placed in his knowledge and learning. Now, any one of good mind may become learned, but only a few persons can teach. Only a young mind can ever teach, whatever the age of the teacher. In colleges the teaching function is likely to be subjugated to the research function or the specialist function; and the mass of students is sacrificed to the few. Freshmen and the general classes are far the most important, not the special students here and there. The special advanced students usually have interest and momentum enough to enable them to make their own way with the minimum of effort on the part of the teacher. Many a teacher in the secondary schools will give the pupils a better grasp on the subject and a broader point of view than a learned college professor, and for the very good reason that such teacher is not so conscious of his scientific reputation as to be afraid to teach. He is blest with what some good persons call a "superficial" view of the subject. A good teacher in the secondary schools is able to get along with not very much expensive laboratory equipment. I am convinced that some of our equipment is too expensive and too complete for the best teaching, however necessary it may be for research. Some high schools have emulated the equipment of colleges until they have more apparatus than they need, and when this occurs it becomes a positive handicap. Both in colleges and secondary schools we need to get back to directness and simplicity. Our first aim should be to develop experience and to give a point of view.

We are likely to place too great value on the mere subject-matter of any course of study. In colleges we must come to a time when students do not choose subjects merely by their names in the catalogues. Sometime we will make our courses of study in terms of the men who teach. I am sure that our colleges are turning out a vast number of uneducated persons.

d There is a rapidly rising interest in the teaching of agriculture and other industrial subjects. This, I take it, is only another expression of the feeling that our education must be made vital and applicable. I am looking to the teaching of agricultural subjects in both colleges and public schools as a means of introducing a new type of educational effort. We shall probably find when we come to write a history of education a few years hence, that the agricultural colleges have made a very great contribution to constructive pedagogy. We shall find also that their influence will have had marked effect on the type and mode of teaching in all public schools everywhere. It is not so much that the subject is agriculture as it is that the teaching is directly related to the normal development of the pupil or the student.

e There is a widespread and growing interest in the nature study spirit. We are gradually coming to realize that nature study is not a subject to be added to a curriculum so much as it is a mode of teaching. Neither is it a "method," as that term is understood in normal schools and elsewhere. The nature study mode is to teach the things nearest at hand and to teach them for the sake of the pupil rather than for the sake of the subject. It takes a pupil out of doors and into touch with the natural world of men and animals d plants and to the earth on which we live.

It has been said that the nature study movement applies specially to the secondary schools. I have come to feel that there is just as much need of it in the colleges as in the public schools for the work of colleges also may be barren.

f My thesis then is this: as science teachers we should be interested more in the student than in the science; the student needs point of view and conception; the science teaching should be vital, relevant, meaningful and applicable.

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Wardwell, Mary M., 505 Ashland av., Buffalo, Central High School
Weed, Henry T., 76 Court st., Brooklyn, Manual Training High School
Welch, Emily H., Packer Collegiate Institute, Brooklyn
Wetmore, Edward W., State Normal College, Albany
Whitney, E. R., 20 North st., Binghamton, High School
Wilcox, C. C., Starkey Seminary, Eddytown
Wilder, Burt G., Cornell University, Ithaca
Williams, Mary E., 125 Clinton av., Cortland, High School
Williston, Arthur L., Pratt Institute, Brooklyn
Willock, James H., St Stephen's College, Annandale
Winslow, E. J., Elmira Free Academy
Wood, Thomas D., Teachers College, New York
Woodhull, John F., Teachers College, New York
Woodsworth, Philip B., Lewis Institute, 5808 Ohio st., Chicago, Ill.

INDEX

Action, summary of, 9–10.
Arrangements, local committee on, 4.
Auditing committee, report, 9.

Bailey, L. H., Science Teaching, 110–15.
Biological survey project, committee to aid in, 4; report of committee, 10.
Biology, 54–61; in secondary schools, committee on, 4; in our high schools, factors that make for success in the teaching of, by H. H. Whetzel, 21–23; secondary, aim and method in, by Martha F. Goddard, 24–32; teaching in Switzerland, 28; experimental work in, by Cyrus A. King, 102–6; first year, in New York city, by Zillah Heidenheim, 97–101.
Biology teaching, some by-products of, by Benjamin C. Gruenberg, 33–43.
Blaker, Ernest, inspector of laboratories of Rockefeller Hall under direction of, 13–15.

Chamot, E. M., Purification of Water, 109.
Children's museum, work of, by Anna Billings Gallup, 54–61.
Committees, 4; report, 10.
Cornell University, vote of thanks to, 10; inspection of laboratories of Rockefeller Hall, 13–15.
Crittenden, E. C. & Waggoner, C. W., Some Experiments Illustrating Wave Motion and Methods of Projection, 18–20.

Earth science, 62–64, 107–15.
Electrical oscillations, by J. S. Shearer, 63–64.
Electricity, elementary, suggestions regarding the teaching of, by R. C. Gibbs, 16–17.
Evolution, instruction in biology from the standpoint of, 26.
Executive council, 3.

Federation, committee on, 4.
Franklin, William S., The Study of Science by Young People, 65–94.

Gallup, Anna Billings, Work of a Children's Museum, 54–61.
Gibbs, R. C., Some Suggestions Regarding the Teaching of Elementary Electricity, 16–17.
Goddard, Martha F., Aim and Method in Secondary Biology, 24–32.
Gruenberg, Benjamin C., Some By-products of Biology Teaching, 33–43.

Hall, Cuthbert, mentioned, 31.
Heidenheim, Zillah, First Year Biology in New York City, 97–101.

Ithaca region, physiographic features, 62.

King, Cyrus A., Experimental Work in Biology, 102–6.
Kittredge, R. J., death, 10.

Laboratories, of Rockefeller Hall, inspection of, 13–15; use of a wet laboratory in physiography teaching, by Oscar D. von Engeln, 44–49; laboratory work in physiography, its advantages and dangers, 50–53.

Martin, Jennie T., Power Questions and their Value, 107–8.
Members, list, 116–19.

Necrology, 10.
Nominations, 9.

Officers, 3.

Physics, measurement of very high and of very low temperatures, 11-12; inspection of laboratories of Rockefeller Hall, 13-15; some experiments illustrating wave motion and methods of projection, 18-20; study of, 82-87; course for secondary schools, 87-94.
Physics teachers, committee on new move among, 4.
Physiography, laboratory work in, by Mary Gertrude Sullivan, 50-53; use of a wet laboratory in teaching, 44-49.
Physiology, aim in teaching, 36.
Power questions and their value, 107-8.
Purification of water, by E. M. Chamot, 109.
Pyrometers for measuring high temperatures, 12.

Rays, educational use of, 95-96.

Science, in Swiss and American schools, 24; study of by young people, by William S. Franklin, 65-94; teaching, by L. H. Bailey, 110-15.
Section officers, 10.
Sessions, summary of, 5-8.
Sharks and rays, educational uses of, by Burt G. Wilder, 95-96.
Shearer, J. S., The Measurement of Very High and of Very Low Temperatures, 11-12; Electrical Oscillations, 63-64.
Sullivan, Mary Gertrude, Laboratory Work in Physiography, its Advantages and Dangers, 50-53.

Temperatures, measurement of very high, and of very low, by J. S. Shearer, 11-12.

von Engeln, Oscar D., Use of a Wet Laboratory in Physiography Teaching, 44-49; on physiographic features of the Ithaca region, 62.

Waggoner, C. W. & Crittenden, E. C., Some Experiments Illustrating Wave Motion and Methods of Projection, 18-20.
Water, purification of, 109.
Wave motion and methods of projection, experiments illustrating, by C. W. Waggoner and E. C. Crittenden, 18-20.
Whetzel, H. H., Factors that make for Success in the Teaching of Biology in Our High Schools, 21-23.
Wilder, Burt G., Educational Uses of Sharks and Rays, 95-96.

Education Department Bulletin

Published fortnightly by the University of the State of New York

Entered as second-class matter June 24, 1908, at the Post Office at Albany, N. Y., under the act of July 16, 1894

No. 459 ALBANY, N. Y. November 15, 1909

PROCEEDINGS OF THE
13th ANNUAL MEETING
OF THE
NEW YORK STATE SCIENCE TEACHERS ASSOCIATION

Held at Syracuse University, Syracuse, N. Y., December 29-30, 1908

PAGE
Officers 1908 3
Executive council 3
Committees 4
Summary of sessions 5
Summary of action 9
General session 15
Address of Welcome: J. L. Heffron 15
Response: O. C. Kenyon 19
High School Agriculture: G. F. Warren 21
A Science Course for Elementary Schools: O. C. Kenyon 20
Inspection of Laboratories and Apparatus Exhibits 39
Section meetings 42
Section A—Physics and chemistry
  Ionization Theory: H. A. Carpenter 42
  A Method and Apparatus for Detecting and Exhibiting the Fluorescence of Fluorescent Substances: W. G. Levison. 52
  Wireless Telegraphy: C. L. Harrington 55
Section B—Biology
  Demonstration of the Work on Types in the First Year Course in Biology: W. M. Smallwood 57
  Round Table Conference on the Syllabus 57
Section C—Earth science
  Relative Insolation Demonstration: F. L. Bryant 58
  Demonstration of a Map and Modeling Apparatus: I. D. Scott 59
General meeting 62
Science Teaching in Secondary Schools: C. F. Harper 63
Section meetings 65
Section A—Physics and chemistry
  The Chemist versus the Trained Workmen: R. L. Fernbach. 65
  Demonstration of Physical Apparatus: Charles Forbes .. 71
  Some Practical Physics Apparatus: William Timbie 77
  A Simple Hydrogen Sulphid Generator: J. P. Hanna 80
  Demonstration of Dynamo and Motor: B. O. Burgin 90
  Brief Demonstrations: C. L. Harrington 93
  Cross Section Drawings for School Use: S. B. Everts .. 95
Section B—Biology
  Ideals of Biology Teaching: A. G. Clement 100
  The Present and Future of Physiology in the High School: C. G. Rogers 104
  Recent Progress in Artificial Illumination: H. M. Smith. 115
Members 1909 131
Index 137

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

1909

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STATE OF NEW YORK

EDUCATION DEPARTMENT

Regents of the University
With years when terms expire

1913 Whitelaw Reid M.A. LL.D. D.C.L. *Chancellor* New York
1917 St Clair McKelway M.A. LL.D. *Vice Chancellor* Brooklyn
1919 Daniel Beach Ph.D. LL.D. - - - - - - - Watkins
1914 Pliny T. Sexton LL.B. LL.D. - - - - - Palmyra
1912 T. Guilford Smith M.A. C.E. LL.D. - - - Buffalo
1918 William Nottingham M.A. Ph.D. LL.D. - - Syracuse
1910 Chester S. Lord M.A. LL.D. - - - - - - - New York
1915 Albert Vander Veer M.D. M.A. Ph.D. LL.D. - Albany
1911 Edward Lauterbach M.A. LL.D. - - - - - New York
1920 Eugene A. Philbin LL.B. LL.D. - - - - - - New York
1916 Lucian L. Shedden LL.B. LL.D. - - - - - - Plattsburg
1921 Francis M. Carpenter - - - - - - - - - Mount Kisco

Commissioner of Education
Andrew S. Draper LL.B. LL.D.

Assistant Commissioners
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Frank Rollins Ph.D. *Second Assistant*
Thomas E. Finegan M.A. Pd.D. *Third Assistant*

Director of State Library
James I. Wyer, Jr, M.L.S.

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John M. Clarke Ph.D. LL.D.

Chiefs of Divisions
Administration, Harlan H. Horner B.A.
Attendance, James D. Sullivan
Educational Extension, William R. Eastman M.A. M.L.S.
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Inspections, Frank H. Wood M.A.
Law, Frank B. Gilbert B.A.
School Libraries, Charles E. Fitch L.H.D.
Statistics, Hiram C. Case
Trades Schools, Arthur D. Dean B.S.
Visual Instruction Alfred W. Abrams Ph.B.

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OFFICERS 1908

President, O. C. Kenyon, Central High School, Syracuse
Vice President, W. M. Smallwood, Syracuse University
Secretary-treasurer, Ernest R. Smith, North High School, Syracuse

EXECUTIVE COUNCIL

Terms expire 1911

E. R. Von Nardroff, Stuyvesant High School, New York
C. B. Robertson, Cortland Normal School
M. A. Bigelow, Teachers College, New York city

Terms expire 1910

G. M. Turner, Masten Park High School, Buffalo
T. C. Hopkins, Syracuse University
Charles Newell Cobb, Education Department, Albany

Terms expire 1909

A. P. Brigham, Colgate University, Hamilton
C. E. Harris, East High School, Rochester
Howard Lyon, Oneonta Normal School

Terms expire 1908

L. V. Case, Washington Irving High School, Tarrytown
W. T. Morrey, Morris High School, New York city
J. S. Shearer, Cornell University, Ithaca

COMMITTEES

Committee on physics

JOHN F. WOODHULL, Teachers College, New York
J. S. SHEARER, Cornell University
O. C. KENYON, Central High School, Syracuse
E. S. WETMORE, Normal College, Albany
L. E. JENKS, Ogdensburg Free Academy

Committee on biology

W. M. SMALLWOOD, Syracuse University
ESTHER F. BYRNES, Girls High School, Brooklyn
L. S. HAWKINS, Cortland Normal School
L. B. GARY, Central High School, Buffalo

Committee on federation

JOHN F. WOODHULL, Teachers College, New York
GEORGE M. TURNER, Masten Park High School, Buffalo
HOWARD LYON, Oneonta Normal School

Local committee for the university

HENRY A. PECK, ERNEST N. PATTEE, T. C. HOPKINS, WILLIAM A. METZLER, ROYAL A. PORTER, CHARLES G. ROGERS, H. MONMOUTH SMITH

Local committee on exhibits

JAMES H. HALL, Technical High School
FRED HARTWELL, Central High School
JOHN W. SCOVILLE, Central High School
FRANK F. DUNHAM, Madison School

SUMMARY OF SESSIONS

TUESDAY MORNING, DECEMBER 29

Council meeting. Room 205, Lyman Hall of Natural History

Registration of members. Room 117

General session

Union meeting with the nature study section of the New York State Teachers Association, President, H. C. DeGroat, Grammar School 31, Buffalo. Room 117, Lyman Hall

Address of Welcome, Dr John L. Heffron, Dean of the Medical College, Syracuse University

Response, President elect O. C. Kenyon, Central High School, Syracuse

High School Agriculture

G. F. Warren, Cornell University

Discussion

A Science Course for Elementary Schools. (a) Of What Shall It Consist? (b) How Shall Its General Adoption in This State be Secured?

O. C. Kenyon, Central High School, Syracuse; L. S. Hawkins, Cortland Normal School; Augustus Klock, High School, Beverly, Mass.; John F. Woodhull, Teachers College, New York; C. Edward Jones, State Education Department, Albany

Discussion

TUESDAY AFTERNOON, DECEMBER 29

Inspection of apparatus and of such demonstrations as the separate exhibitors may choose to give. A printed list of these exhibits will be distributed at the meeting.

The nature study and high school agriculture exhibits will be in rooms 205 and 208, Lyman Hall of Natural History; biology in room 216; earth science, room 310; physics exhibit in Steele Hall; chemistry in Bowne Hall; electrical and mechanical engineering in Lyman Cornelius Smith College of Applied Science.

Demonstration of Brennan Mono-rail Gyroscopic Car

J. S. Shearer, Cornell University

Section meetings

Section A — Physics and chemistry. Room 307, Bowne Hall of Chemistry. C. L. Harrington, *chairman*, Institute of Arts and Sciences, Brooklyn

Ionization Theory — Demonstration, with application to electrolysis
HARRY A. CARPENTER, Rochester West High School

A Method and Apparatus for Detecting and Exhibiting the Fluorescence of Fluorescent Substance. Illustrated
WALLACE GOOLD LEVISON, Brooklyn

Wireless Telegraphy — Lecture, fully illustrated
C. L. HARRINGTON

Section B — Biology. Room 209, Lyman Hall of Natural Science. L. S. HAWKINS, *chairman,* Cortland Normal School

Demonstration of the Work on Types in the First Year Course in Biology, under the direction of W. M. SMALLWOOD, Syracuse University

Round Table Conference on the Subject-Matter of the Syllabus

Section C — Earth science. Room 310, Lyman Hall of Natural History. W. W. CLENDENIN, *chairman,* Wadleigh High School, New York

Relative Insolation Demonstration
FRANK L. BRYANT, Erasmus Hall High School, Brooklyn
Discussion

A Demonstration of a Map and Modeling Apparatus
Prof. IRVING D. SCOTT, University of Michigan

General session

Union meeting with the Associated Academic Principals, L. F. HODGE, Malone, President. Room 117, Lyman Hall of Natural History

Equipment, Condition and Methods in Science Teaching in Secondary Schools
Prin. CHARLES F. HARPER, Central High School, Syracuse

Discussion opened by FRANK ROLLINS, Assistant Commissioner of Education; HOWARD LYON, Oneonta Normal School

TUESDAY EVENING, DECEMBER 29

Union meeting under the direction of the Associated Academic Principals. Lincoln Hall, Central High School

Agriculture and Its Educational Needs
Hon. A. S. DRAPER, Commissioner of Education

WEDNESDAY MORNING, DECEMBER 30

Section meetings

Section A — Physics and chemistry. Room 307, Bowne Hall of Chemistry. C. L. HARRINGTON, *chairman*

Election of officers

The Chemist versus the Trained Workman
R. Livingston Fernbach, Brooklyn

Demonstration of Physical Apparatus
Prof. Charles Forbes, Columbia University

Some Practical Physics Apparatus
William A. Timbie, Pratt Institute, Brooklyn

Brief Demonstrations
Jennie P. Hanna, Rochester East High School; Bryan O. Burgin, Albany High School; C. L. Harrington, Brooklyn Institute

Plain Cross Section Drawings on Cardboard for School Use
S. B. Everts, Adams High School

Demonstrations in the Power House and Engineering Building
(a) The DeLaval Steam Turbine
(b) A 100-ton Testing Machine
(c) Mercury-arc Transformer and Reflectoscope
William P. Graham and James B. Faulks, Syracuse University

Section B — Biology. Room 209, Lyman Hall of Natural History. L. S. Hawkins, *chairman*

Bird Study in Biology. Illustrated
Guy Andrew Bailey, Geneseo Normal School

Why are the Ideals of Biology Teaching Not Realized?
A. G. Clement, Inspections Division, State Education Department, Albany

The Present and Future of Physiology in the High School
Charles G. Rogers, Syracuse University

Section C — Earth science. Room 310, Lyman Hall of Natural History. W. W. Clendenin, *chairman*

The Use of the Stereopticon in Physiography Teaching. Illustrated
Oscar von Engeln, Cornell University
Discussion

The Use of the Stereoscope in Physiography Teaching
A. E. Osborne, New York city
Discussion

Does Our Syllabus in Physical Geography Need Revising?
General Discussion.

Appointment of committees and election of officers for the ensuing year

Luncheon. Sims Hall. Given by the University to the members of the Science Association

WEDNESDAY AFTERNOON, DECEMBER 30

General session

Room 311, Bowne Hall of Chemistry
  Recent Progress in Artificial Illumination
    HENRY MONMOUTH SMITH, Syracuse University
Room 117, Lyman Hall of Natural Science
  Demonstration with Reflectoscope. Reactions of Microscopic Organisms
    W. M. SMALLWOOD & CHARLES G. ROGERS, Syracuse University

Business meeting

Room 117, Lyman Hall of Natural History

Report of committees

Physics. Revision of Syllabus. Dr JOHN F. WOODHULL
Biology. Revision of the Syllabus. Dr W. M. SMALLWOOD
Committee on resolutions
Report of council meeting
Committee on nominations
Election of officers
Treasurer's report

SUMMARY OF ACTION

General meeting

Report of committee on revision of physics syllabus. The following resolutions were presented by the chairman of the committee, Dr JOHN F. WOODHULL:

Whereas, The local conditions and needs of a community must largely determine the kind of physics which should be taught in its schools;

1 *Resolved,* That the syllabus should be broadened so as to include much more than any school may be expected to teach in one year and that local authorities should select such portions as may be best utilized in connection with their available equipment and the school's environment; that Regents examinations should contain such a number of questions and so distributed as to make it possible for a student who has had a year's work of five periods per week to select the required number to be answered without undue difficulty.

2 *Resolved,* That the use of formulas and of mathematics in the Regents examinations in physics should be considerably reduced.

3 *Resolved,* That the Regents examinations should count for one half in the students final grade in physics and the teacher's marking on the year's work one half, provided neither is below 50% on the usual scale of marking, and provided such marks be filed at the commissioner's office before the examinations occur.

4 *Resolved,* That the physics committee of this association be instructed to communicate in suitable form to the Commissioner of Education the wishes of the association in regard to these matters.

After considerable discussion, each resolution was voted upon separately and adopted.

Report of committee on revision of biology syllabus. The following report and recommendations were presented by Dr W. M. SMALLWOOD, chairman of the committee:

The committee on biology was appointed three years ago. At that time it was felt that the present course in biology in the first year in the high schools was established without its previously having had a good consideration. There were also very evident faults in the course, which it was hoped the committee would investigate and try to improve. The first committee consisted of Professor Peabody of the New York City High School, as chairman, Prof. W. M. Smallwood of Syracuse University and Prof. G. F. Atkinson of Cornell University. The chairman of the committee resigned one year ago. Miss Byrnes was then added, and the next member on the committee made chairman.

As the committee was constituted it was top-heavy with college professors. Realizing that this would be a possible valid criticism against the work of the committee, the chairman suggested that two other members be added, one to represent the normal schools and a second representative from the high schools. This idea appealed favorably to the other members of the committee, and the executive committee of the State Science Teachers Association was asked to approve of the appointment of Prof. L. S. Hawkins of the Cortland Normal School, and Prof. L. B. Gary of the Buffalo High School.

About this time Professor Atkinson resigned from the committee, because he believed it was impossible, without a suitable appropriation, to gather information satisfactory enough to warrant any attempt at revision of the syllabus; and for the further reason that the present course had hardly been in operation long enough to warrant its revision. The personnel of the committee which makes this report, then, consists of but one member of the original committee appointed three years ago. In attempting to gather the information it seemed desirable to give to each member a particular grade of work. Miss Byrnes was assigned to the eastern part of the State, including New York city and Brooklyn. Mr Gary was given the western and central parts of the State. These two members of the committee gathered such information as they could from the many high schools in the State. Mr Hawkins was assigned to the normal schools, and the chairman was held responsible for gathering information from the several colleges.

A uniform letter was issued, which asked for information along the following lines:

1 What do you consider the strong points of the present course in general biology in the high schools?

2 In what particulars is the present course unsatisfactory?

3 Specify what changes you would like to have recommended: (*a*) as to additions; (*b*) as to subtractions; (*c*) as to elaborations; (*d*) any changes not included in *a*, *b* and *c*.

In this way the committee has tried as best it could to collect all the available information with reference to the present course; and while a considerable degree of complaint arises in the high schools, it should be said that they have shown the least interest in answering letters. It should also be stated that it is impossible to get the best kind of information without visiting typical schools. This the committee was unable to do without an appropriation. To this extent our work is subject to criticism; but, in the main, we believe that we have collected a valuable lot of information relative to the present course and possible changes.

In view of the impending reorganization of some of the secondary school work in the State, it seems inadvisable to make a series of detailed recommendations in reference to some special course in biology. If the committee had any way of knowing what the course, or courses, would be in the new scheme of reorganization, they would gladly attempt to formulate as fully as possible such a course, or courses.

On the assumption of the reorganization of the secondary school work, the committee feels justified in making the following general recommendations:

A 1 That all of the required work in physiology, such as is now given in the upper grades and the first year of the high school, be condensed into one course for a half year. In this course the work in anatomy and histology should be reduced to a minimum, and the general problems of physiology — sanitation, personal hygiene, etc.— should receive more attention than is now given to them.

2 That a half year course in nature study or elementary science be given. This course could be very materially benefited by utilizing many of the nature study features in the present biology course.

B We further recommend that the high schools be given the option of establishing a required course for the whole year, selecting any one of the following: botany, biology, physiology or zoology; this course to be so formulated as to be acceptable as a unit subject for college entrance. The reasons for offering an option on these four subjects may be outlined as follows: First of all, there is a wide diversity of situation in this great State, from crowded tenement districts to high schools located in the sparsely populated, mountainous regions. Between these extremes exist all kinds. This diversity alone raises the question of facilities. Certain schools located near accessible ponds and streams, find a course in zoology or botany very easy to give; while others in a more limited environment would prefer to select one of the other subjects. Secondly, the equipment of the schools throughout this large State varies greatly, and, it seems to the committee unwise to attempt, all at once, to bring all of the schools to a similar condition.

It seems to be the unanimous testimony of numerous high school teachers located in the poorer schools, financially speaking, that it is almost impossible to get adequate laboratory equipment. Thirdly, there is an honest difference of opinion among the teachers of the State as to which of these several courses is the more desirable, and until there is a more general unanimity of opinion it would seem entirely warranted to allow some freedom to the respective schools.

In case of no general readjustment in the present courses of the high school, the committee beg leave to recommend the following in reference to the present course in the first year of the high school: First, to strike out the three divisions, botany, physiology and zoology, making the course a unit in treatment as well as in name, under the name of elementary biology. The preliminary report on a biology syllabus for the first year of high school, by the New Jersey Science Teachers Association, indicates one way in which such a unity of treatment is accomplished. In making this recommendation there is no intention to change the general content of the present course, as there would be ample facilities for dealing with the problem of life in plants and animals and the relation of these general problems to human activity. Secondly, the anatomical features of the work in physiology may well be lessened, and in their place considerable time given to the general problem of sanitation, biology of disease, and personal hygiene. It is not necessary for the committee to remind this organization that education along the lines of sanitation, hygiene and disease, is the only general method thus far agreed upon by means of which civilization can be successfully purged of much of its present day weaknesses. Thirdly, that the total number of subjects required in this course be lessened, in order that opportunity be afforded for more concentration. In this connection we would suggest that some of the nature study features of the present course be eliminated, and placed where they more properly belong — in the grades.

W. M. Smallwood, *Chairman*
Esther F. Byrnes
L. S. Hawkins
L. B. Gary

Each resolution was voted upon separately and adopted and then a motion was made and carried that the report as a whole be adopted.

Report of council. A letter was read from Frederick S. Lee of New York urging the cooperation of the association in killing legislation restricting vivisection in colleges and asking if vivisection was practised in the high schools of the State. Council voted to approve the spirit of the letter.

Council recommends to the association that it join the American Federation of the Teachers of Science and Mathematics.

Council voted to leave the matter of appointing the place for the next meeting with the next executive committee.

The above report was read by the secretary. Motion made and carried that the action of the council be ratified.

Report of committee on resolutions was read by Prof. W. W. Clendenin, *chairman:*

Resolved, That we heartily appreciate the courtesy of the University authorities in placing at our disposal their lecture rooms, laboratories, and dormitories;

That we recognize their provision for our physical comfort as no small factor in contributing to the success of our meeting; and

That we tender our sincere thanks for these proofs of their kindly interest in our organization.

Resolved, That we cordially thank the local committee for their untiring, painstaking and successful efforts in making general arrangements, and in providing for the display of exhibits.

W. W. CLENDENIN } *Committee*
S. B. EVERTS }

Moved and carried unanimously that the report of the committee be adopted.

A letter of greeting and good wishes was received from the Associated Academic Principals.

Motion made and carried that the secretary send thanks of the association to the principals for their kind letter.

Report of nominating committee. The nominating committee made the following nominations: *President,* W. M. SMALLWOOD, Syracuse University; *vice president,* C. E. HARRIS, East High School, Rochester; *secretary-treasurer,* ERNEST R. SMITH, North High School, Syracuse

For members of the council (term to expire 1912):
J. S. SHEARER, Cornell University, Ithaca,
F. L. BRYANT, Erasmus Hall High School, Brooklyn,

O. C. Kenyon, Central High School, Syracuse.

Motion was made and carried that the secretary cast the unanimous ballot of the association for those nominated.

Section officers, 1909. The various sections reported the following as the officers elected for the coming year:

Section A. *Chairman,* William A. Timbie, Pratt Institute, Brooklyn; *Secretary,* H. C. Cooper, Syracuse University.

Section B. *Chairman and secretary* to be chosen by the president.

Section C. *Chairman,* C. L. Foster, Colgate Academy, Hamilton; *Secretary* to be chosen by the president.

Federation. Superintendent Bardwell, ex-president of the New York State Teachers Association, spoke in regard to a plan for the federation of the two associations.

Motion was made and carried that the entire matter of federation be left with the present committee on federation.

Treasurer's report

Summary as per books and vouchers on file for the year ending December 30, 1908

Receipts

Dec. 28, 1907	Balance from Treasurer Stannard	$172 16
Dec. 30, 1908	Dues to date, including interest	172 98
	Total	$345 14

Expenditures

Dec. 30, 1908	Total to date	$157 40
Dec. 30, 1908	Balance on hand	187 74
	Total	$345 14

Report of auditing committee. We, the undersigned auditing committee, have examined the accounts and vouchers of Treasurer E. R. Smith and have found them correct.

J. E. Stannard }
L. E. Jenks } *Committee*

December 30, 1908
Report accepted

Note. By permission of the auditing committee, several bills that belonged to the 1908 meeting but which had not been received, were paid ater and included in the above report.

GENERAL SESSION

Tuesday morning, December 29

Union meeting with the nature study section of the New York State Teachers Association

ADDRESS OF WELCOME

DR JOHN L. HEFFRON, DEAN OF THE MEDICAL COLLEGE, SYRACUSE UNIVERSITY

Mr President and Fellow Teachers: The pleasant duty has been given me of bidding you welcome to our city and to our university. Syracuse emblazons on the front face of her City Hall, the legend, " Syracuse Bids You Welcome." Whether it catches your eye in the light of day, or glows in electric light by night, it is ever significant of the sentiment of hospitality which animates her citizens. But for you, who mold the minds and inspire the thoughts and the actions of the boys and girls that tomorrow shall be our citizens, she has an especial welcome.

In welcoming you to Syracuse University, you will be conscious of the absence of our chancellor, whose words would warm your hearts and animate your minds. Syracuse is the youngest of the larger universities. If you will remember that, you will easily excuse what appears to some as a rather ragged campus.

The work of building in recent years has been so enormous that sufficient time has not been had to mold the campus into a symmetrical whole. But if you will give your imagination full play, you will see the possibilities of our future. The corner stone of the College of Liberal Arts was laid August 31, 1871. Since then growth has been constant, but within the administration of Chancellor Day, all the buildings which Syracuse University has, except the College of Liberal Arts, The Holden Observatory, and The John Crouse College, have been erected or acquired or replaced and that within the period of 12 years. We acknowledge youth, but we feel that if the primary duty of youth is to develop a strong physical status, we have gone far towards that attainment.

We have been fortunate in our chancellors. The second chancellor, Dr Winchell, was a scientist of repute. He laid broad the foundations of a strong scientific department that has been built upon in each succeeding administration. No teacher has been limited in his work. The demonstration of the truths of science has always been encouraged, and truth has never been sacrificed to preconceived opinions. With the present scope of scientific teaching in our university, you shall become familiar, if you choose.

And now what shall I say to the first question propounded by your president? "What are we teaching science for?" This is a question so large that it can not be fully discussed in 10 minutes, but I may be permitted to state a few of the reasons why science should be taught.

Why do we teach anything? First, for the acquirement of knowledge; then for the discipline of the mind; and, finally, for its bearing upon the daily conduct of life.

Probably no teacher amongst English speaking people has had so great an influence upon his times and upon our own as Thomas Huxley. Born in 1825, he devoted the whole of his 70 years of life to the study and the teaching of the great truths of science. Such a man should be good authority. Permit me to restate his conceptions of a liberal education — a conception which to my mind has never been surpassed. "That man, I think, has had a liberal education who has been so trained in youth that his body is the ready servant of his will, and does with ease and pleasure all the work that, as a mechanism, it is capable of; whose intellect is a clear, cold logic-engine, with all its parts of equal strength and in smooth working order; ready, like a steam engine, to be turned to any kind of work, and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with the knowledge of the great and fundamental truths of nature and of the laws of her operations; one who, no stunted ascetic, is full of fire and life, but whose passions are trained to come to heel by a vigorous will, the servant of a tender conscience; who has learned to love all beauty, whether of nature or of art, to hate all vileness, and to respect others as himself. Such a one, and no other, I conceive, has had a liberal education; for he is, as completely as a man can be, in harmony with nature. He will make the best of her, and she of him. They will get on together rarely; she as his ever beneficent mother; he as her mouthpiece, her conscious self, her minister and interpreter."

If we agree to this statement of what constitutes a liberal education, let us ask him the best way to attain it by the paths of science. In reference to the positions and scope of the natural sciences as a branch of knowledge, he says: "The distinctive character of our own times lies in the vast and constantly increasing part which is played by natural knowledge. Not only is our daily life shaped by it, not only does the prosperity of millions of men depend upon it, but our whole theory of life has long been influenced, consciously or unconsciously, by the general conceptions of the universe, which have been forced upon us by physical science."

And in another address he says: "Leave out the physiological sciences from your curriculum, and you launch the student into the world, undisciplined in that science whose subject-matter would best develop his powers of observation; ignorant of facts of the deepest importance for his own and others' welfare; blind to the richest sources of beauty in God's creation; and unprovided with that belief in a living law and an order manifesting itself in and through endless change and variety, which might serve to check and moderate that phase of despair through which, if he take an earnest interest in social problems, he will assuredly sooner or later pass."

Such observations could be confirmed and amplified by many other authorities, but they are now a part of our own organized thought upon this question and no longer need defense.

Of the value of science as a means of mental discipline, Huxley was the first to speak boldly. From his address on "Science and Culture," let me repeat his statement of what constitutes culture: "Culture certainly means something quite different from learning or technical skill. It implies the possession of an ideal, and the habit of critically estimating the value of things by comparison with a theoretic standard. Perfect culture should supply a complete theory of life, based upon a clear knowledge alike of its possibilities and of its limitations."

In his analysis of the methods by which culture is attained in the study of science he emphasizes: (1) observation of facts, including artificial observation which is called experiment; (2) comparison or classification, by which one arrives at general observation; (3) deductions, which takes one from general propositions to facts again; and (4) verification, which is the process of ascertaining whether in point of fact our anticipation is a correct one.

These are the methods of science. They necessitate the exercise of memory, imagination, reason and judgment. Of the effect of the exercise of these faculties of the mind by means of the study of science, he asserts modestly and, I believe, truthfully, that "for the purpose of attaining natural culture, an exclusively scientific education is at least as effectual as an exclusively literary education." But repeatedly in his many addresses he deprecates an education one-sided in any direction.

In discussing the practical value of a scientific education we are forced to consider its mental and moral value, its contribution to the pleasure of life, and its physical or technical value. Concerning the first he says: "The mental power which will be of most importance in your daily life will be the power of seeing things as they really are without regard to authority; and of drawing conclusions from particular facts."

That scientific education has a practical moral effect is not to be questioned. Huxley's quotation from Worthington is significant. "It is not easy to exaggerate the importance of the information imparted by certain branches of science. It modifies the whole criticism of life made in maturer years. The study has on a mass of boys a certain influence to which a great deal of value must be attached, an influence as much moral as intellectual, which is shown in the increased and increasing respect for precision of statement and for that form of veracity which consists in the acknowledgment of difficulties. It produces a real effect to find that nature can not be imposed upon, and the attention given to experimental lectures, at first superficial and curious only, soon become minute, serious and practical." Nature yields her secrets only to those who pursue honest methods of investigation, and honesty is the basis of morals.

Huxley says: "There is yet another way in which natural history may take a profound hold upon practical life, and that is, by its influence over our finer feelings, as the greatest of all sources of that pleasure which is derivable from beauty. I do not pretend that natural history knowledge can increase our sense of the beautiful in natural objects. But I advocate natural history knowledge because it would lead us to seek the beauties of natural objects, instead of trusting to chance to force them upon our attention. To a person uninstructed in natural history, his country or seaside stroll is a walk through a gallery filled with wonderful works of art, nine tenths of which have their faces turned to the wall. Teach him something of natural history, and you place in his hands a catalogue of those which are worth turning around. Surely our innocent pleasures are not so abundant in this life, that we can afford to despise this or any other source of them. We should fear being banished for our neglect to that limbo, where the great Florentine tells us are those who, during this life, "wept when they might be joyful."

Concerning the technical value of scientific education, there is little need to enlarge. It is so great that the mind of the great majority of youths is turned to it alone, and we see the technical courses in our colleges crowded to the neglect of the old "humanities." The triumphs of chemistry, of engineering, of electricity, of biology are so numerous and of such immense importance to the inhabitants of this earth that it is not a matter of wonder that they fill the visions of those who contemplate first of all, " getting on in the world."

I have taken so much of your time that I can not permit myself to discuss the second question propounded by your president — viz: " How Should Physiology be Taught in the Public Schools." I will say this, that it is your duty to see that physiology is taught and not pathology, and to establish so strong a position on this subject that it will mold public opinion to resist the well intended efforts of ignorant though enthusiastic reformers who would make mandatory the teaching to children of subjects upon which scientists are not yet agreed. A child to whom a glowing sunset suggests only " the lining membrane of a drunkard's stomach," knows nothing of physiology, nor of physical sciences, nor of the beauty of the world.

I have full confidence in the genius of American teachers. Much criticism has been given to present methods of education, some of which is just and much of which is unjust. If you will model your methods of education upon the methods of science, you can not fail to evolve methods which will enable the children of today to come into knowledge and possession of themselves, and of the world in which they live, and of its people and their achievements.

RESPONSE

PRESIDENT ELECT O. C. KENYON, CENTRAL HIGH SCHOOL, SYRACUSE

Speaking for the Science Association, and also as a member of the State Teachers Association, I wish to assure Dr Heffron and the authorities of Syracuse University that we thoroughly appreciate their good will and generosity in opening these buildings and laboratories for us; and that we realize, also, the sacrifice which many of the faculty are making in remaining here to welcome and help us, when, as we know, they would prefer to be at other meetings in other places.

As this is the fifth time we have met at this university (twice before at the Medical College and twice in the Liberal Arts Building), we are only adding to a debt already large, not only for entertainment and active assistance, but also for that encouragement and inspiration which come to us from meeting and hearing those who are engaged in advanced lines of work. The Science Teachers Association has been exceedingly fortunate in having had from the beginning the cooperation of the science faculties of the colleges.

We who are high school and normal school teachers can only hope that in consequence of such efforts we may be able to better prepare our students for college and for life.

We appreciate and take to heart the words of the preceding speaker, and they will no doubt have especial influence because they come from a leader in that great and noble profession of medicine which in its foundations and progress belongs to the same department of knowledge and education as that in which we are at work.

Concerning the program for this morning, I may say that it has been brought over or continued from the preceding meeting. Those of you who were in Ithaca a year ago and heard Dr L. H. Bailey speak will remember how convincingly he talked of the importance of such science studies as are closely related to the life and needs of the people, and which at the same time assist well in the natural development of the child. He referred in particular to agriculture and nature study as belonging to this class, and claimed that they had already strongly influenced the teaching of science in other departments, especially in secondary schools.

Until a few weeks ago, we expected that Dr Bailey himself would be here to continue this subject, although from a somewhat different standpoint; but, owing to his appointment as chairman of the "Country Life Committee" in Washington, he was obliged to withdraw from his part in the program, which has in consequence been changed. However, we have been fortunate in securing other speakers, as you see from the program, and they will no doubt be able to put us into that altruistic as well as scientific frame of mind which Dr Bailey is so well able to arouse and which as science teachers we should desire and cultivate.

The subject of agriculture has been in our high school course of study for several years and yet its claims have never been presented at any of our meetings, and some of us have only a vague idea of what the study is. That agriculture is our greatest occupation we know, and we have always understood that farm life is itself the best school that we have for the development of character, self-reliance and a vigorous manhood; but is agriculture a science, or is it made up of different sciences and of different occupations, and, whatever it is, is it a suitable study for high schools, and ought we, as science teachers, to welcome it, and assist in giving it a place in our high school course? No doubt but that these questions and many others will be answered by the next speaker, Prof. G. F. Warren of the State College of Agriculture of Cornell University. I have great pleasure in introducing Professor Warren.

HIGH SCHOOL AGRICULTURE

G. F. WARREN, COLLEGE OF AGRICULTURE, CORNELL UNIVERSITY

I am pleased to have the opportunity of addressing this association on an agricultural subject for two reasons.

First, because the Science Association recognizes that agriculture is merely one of a number of sciences which belong in the high school. Frequently persons have failed to recognize the fact that high school agriculture is merely another subject comparable with physics, botany and chemistry, and have classed it with trade school subjects.

Agricultural teaching gives exactly the same type of education as that given by the other sciences. It is merely the study of those particular scientific principles which have to do with the production of plants and animals that are useful to man. It, therefore, involves some of the principles of each of the other sciences.

My second reason for being here is because this is the most important subject before the farmers of America. Professor Bailey says that the one subject that stands out above all others in the hearings of the Country Life Commission from ocean to ocean is the question of education. And everywhere farmers are demanding that somehow our education be brought into vital relationship with the farms. I doubt whether any other class in our population is giving so much attention to education.

To those who are not familiar with the nature of agricultural teaching, it may seem like a trade subject and nothing more, but agriculture is not primarily a trade subject. Only about one half of our population is engaged in agricultural work, but the interest in agriculture includes nearly all the population. A very large part of our city population, particularly of the larger cities, is coming to take the keenest interest in agricultural questions. The number of agricultural inquiries that have come to the College of Agriculture from New York city within the past few years is very remarkable, but no more so than the movement for ownership and management of farms by city men. Nearly every one is interested in growing plants and animals and there are some fundamental principles of this growth that every boy and girl should have an opportunity to learn, if they so desire, not that they may become farmers and farmers' wives, but for the educational training and intelligent interest in life that this knowledge brings. This training is often as desirable for those who are to live in cities as for those who are to live on farms. We can never wholly separate our interests from the soil on which we walk and the plants and animals on which our life depends.

The argument that is most commonly urged in favor of teaching agriculture in the high schools is that it will keep the boys on the farm. At the same time we are told that farming is not as profitable as it should be. Now if we believe in the laws of economics, we must conclude that we have enough farm produce. More farms would decrease the profits for each man.

Then, we have reason to expect that the teaching of agriculture in high schools will develop a better class of farmers who will be able to raise more crops per man. If this is the case, as I am sure it will be, then the better educated our farmers are the fewer of them we will need; at the same time the more manufactured articles these farmers will demand. We will need to have still more farmers move to the city in order to make plows, pianos and automobiles for those who remain farmers.

I believe that the more we teach agriculture the more efficient our farmers will become and the fewer we will need. What will happen is that a different class of boys will go to the cities and for a different purpose. As farming comes to be a skilled profession, there will be an increasing tendency for the less efficient to move into the cities, where they will work in factories under direction. The factories can use men who are not qualified to make good farmers. The natural road to advancement for the rural laborer is, as it should be, farm ownership. The man who is to be a hired laborer all his days is best off in the city, where the closer supervision can get the most out of his smaller talent. I believe, therefore, that agricultural education will decrease rather than increase the percentage of farmers. It will tend to send the poorest men to the cities, as well as some of the best, and will build up a class of farmers who are farmers because they want to be. If we desire to make men stay on the farms, the most effective way of accomplishing it might be to pass a law that all men who are born on farms must stay there.

It is not the business of a teacher to try to make farmers of farmers' sons, nor lawyers of lawyers' sons, nor doctors of doctors' sons. The thing that distinguishes America from the old world is the mobility of its society. Each man may do what he likes and become what his energy will make him. While it is not desirable to try to make farmers, it does seem desirable to stop unmaking them. The present trend of all our education is cityward. We have been living in a city-making epoch. The bright farm boy, as he has attended the village school, has been taught much that would naturally interest him in city occupations. The teacher has become interested in him and has encouraged him to "make something of himself." This usually means that he become a lawyer, doctor or, perhaps, an engineer. The nature of his books and the advice of his friends have led him to believe that these were the lines in which mental ability could bring the greatest returns. If he did become a farmer, he frequently felt that by doing so he lost his real opportunities. In the past, this may have been so, but, today, law, medicine and the ministry are not the only learned professions. The practice of agriculture now offers as great a field for scientific study as is offered by the practice of medicine.

The teaching of agriculture will make better farmers who will make more money. It will lead boys to choose farming as a profession, for it will open up a field for intellectual life whose existence they never suspected, but the great reason for this work is that it is one of the best means for training the student's mind and it is one of the best means because it studies things that come within his experience — the things with which and by which he lives.

All the arguments that may be presented in favor of science teaching may also be applied to the teaching of agriculture. The great competitor of science has always been the foreign language studies. I think that we often forget how these studies came to be. Originally nearly all knowledge was locked up in the Greek and Latin books. He who would learn anything must first learn to read the languages in which these books were written. But gradually the despised English has come to have some books of its own and we no longer look to Latin and Greek as content studies. Their reason for existence at present must be based on entirely different arguments than those which first caused them to be taught. Not infrequently, it seems to me that the chief argument in the student's mind, at least, and sometimes in the teacher's, for giving instruction in these languages in the high school is that the student may learn them in order that he may teach them in turn to another set of students, who may teach to a still later generation. I do not wish to be understood as opposed to such instruction in the high school. The only point that I would wish to make is that we should not require all persons to take foreign language studies. All that most persons gain from such study in the high school is the mental drill and discipline and a somewhat improved knowledge of English. These points are well worth considering and we will have no quarrel with the teacher of language as soon as the teacher of language recognizes that the primary purpose of education is to train men for the lives that they are to live. In general, I believe that our schools have given too much time to expressional studies and too little time to content studies.

As a matter of fact, the introduction of sciences has not decreased the total number of persons who study language. The percentage of such students may decrease, but the sciences attract and hold large numbers of students who would not otherwise be in the school. Agriculture will attract a still larger number in the rural high schools.

A very large part of our agricultural instruction may be combined with other sciences and will serve to enrich these studies. I believe that agricultural illustrations will almost revolutionize the teaching of science, which is in danger of becoming too academic. As soon as we get a science well systematized with definite sets of laboratory exercises, which we feel are fixed for all time, we have lost one of the most useful features about science, that is, that it studies the earth and the civilization that surrounds us — conditions that are ever changing.

While teaching capillarity in physics, the soil offers a most useful illustration. While teaching friction, such questions as the relative draft of riding and walking plows may be cited. A well constructed riding plow will carry a man and draw easier than will a walking plow, because a third of the draft of the walking plow is due to friction on the bottom of the furrow, whereas with the riding plow the friction is placed on the axle and the axle is greased. Another illustration might be given of the reason why placing the doubletree below the tongue will enable a team to pull a heavier load than if the doubletree is high as in the case of carriages. The first thing that gives way when a horse fails to pull a load is the feet. The horse can not stick to the ground, but if hitched low a part of the load will pull down on the back, making the horse heavier and the fricton greater, and will enable the horse to pull more. This is also one of the reasons why a draft horse should be heavy.

While teaching bookkeeping in rural high schools, farm accounts rather than operations involving some large city business should be used for at least a part of the illustrative material. Farm accounts are more complicated than are the accounts for city businesses. They would, therefore, better meet the objection that some persons have to bookkeeping — that it does not require sufficient mental application. Agricultural illustrations may fairly revolutionize the teaching of botany. Similar illustrations may be multiplied indefinitely.

Since agriculture is based on all the sciences, some persons have argued that it can best be taught by having the principles presented in the separate sciences, as illustrated above, rather than by having a new subject. This argument may sound logical, but it is utterly impracticable. In the first place, our textbooks on science are now written and we can only change them gradually. The knowledge of agriculture is rapidly increasing which would involve the rewriting of all the science textbooks every few years. It will be a simpler matter to rewrite only the books on agriculture.

In the second place, if all the agriculture were taught through the sciences, it would require that each teacher of science should know considerable about agriculture. It will be difficult enough to secure one teacher for each school who has this knowledge. I believe most thoroughly in having agricultural illustrations used in the teaching of science, because the science teaching would be so much improved, but we must still have a separate subject of agriculture. Agriculture is based on many sciences just as is the science of medicine, if agriculture and medicine are sciences. I do not think that the time will ever come when our instruction in medicine will be given by the college teachers of zoology, botany, physics and chemistry. No matter how many medical illustrations these teachers may use, they must always have separate departments and separate instruction that will correlate all the sciences in a single unit, the science of medicine. Similarly we must have the sciences correlated in the single unit — agriculture.

Let us take a single illustration. How would the teaching of crop rotation proceed if there were no special teacher of agriculture? Crops are rotated (1) to control weeds; (2) to control insects; (3) to control fungi; (4) to keep up the humus supply; (5) to secure the benefits of growing grasses and legumes on each field; (6) for convenience in working; (7) for the control of toxic substances.

Possibly the botany teacher might mention weeds, fungi, legumes and grasses in this connection, and might even discuss toxic substances. The teacher of zoology might mention a crop rotation as a means of controlling insects, but to have these points mentioned at various times and in a disconnected way would not teach the importance of crop rotations. All the reasons must be grouped together under this one head and considered at one time in order to bring out effectively the importance of the subject.

But more important than the reasons for crop rotation is the training in the planning of cropping systems. After having studied the reasons, the class should take up a particular farm and plan a cropping system for it.

Temporarily our agricultural colleges have to give special work which is practically of a high school grade. They do this in addition to their regular college work. The New York State College of Agriculture has graduate students, college students and has special and winter course students who are practically of a high school grade, but are older and more mature than are high school students.

Gradually the academies and certain special high schools will also do special work for persons who are too old to attend the regular high schools.

The normal schools must take up the work if it is ever to become effective. Some persons fear that elementary agriculture is too difficult a subject for the rural schools, but this subject is merely nature study on agricultural topics. Most of our present nature study is adapted to city schools. What we now need, whatever we may call it, is nature study on agricultural subjects for the rural schools. The best way to get this is to teach high school agriculture in the normal schools.

But more important than all of these, so far as the number of persons to be reached is concerned, is the teaching of agriculture as a regular subject in the regular high schools, where it will take its place as a subject comparable with algebra, chemistry or Latin, always being elective.

There are several reasons why the other classes of schools are not sufficient. The first, of course, is that the great majority of students will never go beyond the high school, and the second, which is equally important, is that most students of a high school age should sleep at home.

In a high school, agriculture would merely take its place as one study which may be carried for one, two or more years. I think that it should be taken for at least one year, but even a smaller amount of time may be all right in the beginning, when the subject is being tried out. It will naturally replace some of the foreign language study, but as you will see by the suggested courses in the high school exhibit, it does not necessarily prevent the student taking two or three years in foreign language. It is much to be preferred, in fact, it is almost essential, that chemistry and botany precede or accompany agriculture. If chemistry is not taught, some few exercises in chemistry should be given in agriculture. For those students who plan to graduate, agriculture may come in the eleventh year in the high school.

If the subject is introduced, there will undoubtedly be a large number of boys who will wish to attend school for one year, who would otherwise not attend at all. For such persons, I think that we should allow a selected course taken from all the years of the high school. It might be well to include botany, chemistry, physics, agriculture and American history, or we could arrange a two year course in which these subjects, advanced arithmetic, bookkeeping, physical geography and similar work might be included. I believe that our high schools should arrange to accommodate those persons who are unable to attend four years just as well as to accommodate those who graduate. This can be done in many cases by allowing them to select a course of the kind of studies that attract the boys, who ordinarily leave the school early, rather than by forcing all of them to take what we think will be best and which results in not having them at all.

The following suggested high school courses show how agriculture may be introduced. These courses are not my ideal. I make no recommendations as to whether there is too much or too little of anything except agriculture, bookkeeping and arithmetic and science. The remainder of the courses are what many schools are teaching. My effort is to show how effective agricultural work may be given with as few other changes as possible. The courses will differ in each school. These are merely suggestive examples. If the electives are so arranged as to secure three years of German or French and three years of English, either of these courses will prepare for entrance to the New York State College of Agriculture as well as for farming.

The following are given as possible high school courses:

ONE YEAR OF AGRICULTURE

First year
- English
- Algebra
- Latin, German or French
- Biology or botany

Second year
- English
- Geometry
- Latin, German or French
- History

Third year
- English
- Mathematics or elective
- Chemistry
- Elective

Fourth year
- English
- Agriculture
- Physics
- Bookkeeping and arithmetic

TWO YEARS OF AGRICULTURE

First year
- English
- Algebra
- Latin, German or French
- Biology or botany

Second year
- English and physical geography
- Geometry
- Latin, German or French
- Chemistry

Third year
- English
- Mathematics, history or elective
- Physics
- Agriculture

Fourth year
- American history and civics
- Bookkeeping, farm accounts and arithmetic
- Agriculture
- Commercial geography or elective

We should not expect too much of a new science when it is first introduced. The teachers can not be thoroughly prepared at once. We must gradually develop the subject as we have gradually developed botany and physics, although I think that we can move much more rapidly in the case of agriculture. I do not see why we should not have a thoroughly good course of agriculture developed within the next two or three years and in a short time we may well have teachers prepared for this work. Any person who has had farm experience and who has studied botany, chemistry and physics, may prepare to teach high school agriculture in at least a fairly satisfactory manner by taking a summer's work devoted wholly to this subject. Good work may be done by many such persons by working up the course themselves from the suggestive material which is now prepared. In dealing with any new subject of this kind, we must remember that it takes time. I sometimes think that it would be well to apply the story of the small boy who was being impressed with the omnipotence of the Almighty. After much care in trying to impress him with this point, he replied that he knew something that the Lord could not do. The shocked teacher asked what; and received the reply, " The Lord can't make a two-year old in a minute."

Several schools in the State are now teaching agriculture and are doing excellent work. We have exhibits from two or three such schools and also have an exhibit showing how some of the exercises in the State Syllabus of Agriculture may be carried out. I hope that you may take the time to see this work. I understand that such time is set apart for this afternoon.

A SCIENCE COURSE FOR ELEMENTARY SCHOOLS

Pres. O. C. Kenyon—As regards the next topic for discussion, "Science for Elementary Schools," while it is not a new subject with us, it is one to which, it seems to me, we have not given that earnest and enthusiastic support which we have lent to other subjects. And yet this is one of the principal objects for which the Science Association was formed. At our first annual meeting, in 1896, a "committee of nine" was appointed to secure three results: first, the recognition of science as a requirement for entrance to college; second, the development and strengthening of science courses in secondary schools; third, the establishing of nature study in elementary schools. The first two of these aims seem to have been fairly well accomplished. High school science, with accompanying laboratory work, is accepted by the colleges, required by the State, and generally recognized as an essential and important part of the high school course.

But what have we done for nature study? In the first address, by a president of the Science Association, Prof. Simon T. Gage, of Cornell University, made a plea for cooperation on the part of all science teachers in helping not only the colleges and high schools but also the elementary schools, the professions, and the public generally to acquire some knowledge of science. "Our association," he said, "ought not and can not stop with the work of the high school. From the elementary schools, most people enter upon the labors of life; they are the bulk of the State, and a noble patriotism should lead us to do all we can for them. As the college reaches down to help and encourage the high school, so should the high school reach down to help and encourage the elementary school, and thus will it come about that every child in the State will be brought into direct contact with nature where he can experience for himself her inspiring and uplifting sympathy."

In the next year the committee of nine reported as follows: "The importance of a continuous course of nature study in all elementary schools, as an indispensable element in primary education and as a preparation for the study of science in the secondary schools, demands that an immediate effort be made to formulate the objects and lay out the plans for such a course and to surmount the difficulties in the way of its successful operation."

In the year following (1898), a subcommittee of the committee of nine recommended, "that the association endeavor to arrange for the publication and distribution of syllabuses on nature study for the direction of teachers' classes and for the help of teachers in the schools." The committee reported a list of topics for schools; and stated that the objects to be gained by the study were: first, the training of the senses; second, the ability to think about what has been observed; third, sympathy with nature. This meeting was held ten years ago, and up to that time we seemed to have done fairly well; but at the next meeting, for some reason, there was no attention given to this subject. For the following three years, while there was a nature study section, judging from the fact that it was discontinued, it could not have been very successful. During the last six years we have had no nature study section, and only two papers, I think, on this subject, before the general session.

It must appear, therefore, as I suggested, that we have not given to this important subject the consideration which it deserves. We have been busy with other matters, especially with high school problems. But, fortunately for the study, some of our members, and those of other organizations, have kept at work and have made progress. Some of these will tell us how far the movement has gone in this and other states and will make suggestions, probably, as to what should be done at the present time.

Finally, is it not our duty as a body of science teachers, now that the high school field is won, to unite, to remain united, and in vigorous action, in assisting the elementary schools in their effort to extend science teaching, until, as Professor Gage so well said, "every child in the State shall be brought into direct contact with nature where he can experience for himself her inspiring and uplifting sympathy."

I now have the pleasure of giving this meeting into the charge of Prin. H. C. DeGroat of Buffalo, president of the nature study section of the New York State Teachers Association.

President DeGroat then took the chair and presided over the meeting during the reading of the following papers.

L. S. Hawkins — The practical problem, which now confronts the advocates of nature study, is to formulate some general principles which may guide teachers in organizing nature study work. The formation of the American Nature Study Society is a step in the right direction. Professor Bailey, its president, advocates that the society, or a committee from the society, put in concrete form results of the ideas that have been repeatedly expressed. This would at least afford a central point for discussion from which might eventually come a generally accepted basis for a course of study.

Gradually the difficulties which have stood in the way of a general introduction of nature study into the schools are being removed. The teachers are getting in sympathy with the observational methods and are recognizing the general aims of nature study. Superintendents and principals are becoming convinced of the educational and ethical value of nature study. Parents are finally losing the idea that nature study is a fad. In order that there may not be reaction it is quite necessary that our work be organized. The lines of organization may be broad; it seems that they should be broad; but they must be definite if nature study is to have a permanent place in our school curriculum.

Biologists have been most active in establishing nature study in the schools and in working out courses, lessons and suggestions. Biological facts are the basis of most of the textbooks of nature study. As a consequence, in the average teacher's mind, nature study material means plants and animals. We are all agreed that material for nature study comes from the fields of meteorology, geology, mineralogy, physical geography, physics and chemistry, as well as from the field of biology. Why then in our courses, lessons, plans and suggestions permit the biological to dominate? We say that nature study is an attitude of mind. Why not get in this attitude and incorporate in our writings nature study facts rather than biological facts only? If teachers in the public schools are to be in sympathy with the movement, the leaders must be natural scientists instead of biologists, physicists, chemists or geologists. The writer wishes to state here that he has been trained along the lines of biological rather than other science.

In the discussions of aims, methods and materials there has been expressed great difference of opinion. Note for instance the points made in the discussions of Dr Hornaday's article on the weakness of nature study [Nature Study Review. January 1907]. Some of the writers had in mind, as did Dr Hornaday, only the upper grades while others were evidently thinking of the lower grades. Very little emphasis has been placed upon the distinctions that should be made between the first and last years of the work in the elementary school. Almost without exception writers apply to the grades, as a whole, ideas which relate to a limited portion only. A separation of the discussion might harmonize some apparently diverse views. The fifth or sixth year seems to mark some break in school work. Primary (first–fifth) grades are on a different basis from the grammar (sixth–eighth) grades. This division of the elementary school — primary, grades first–fifth: grammar, grades sixth–eighth — appears to be a logical educational distinction and applies not only to subject-matter but also to presentation.

The chief aim in the primary grades should be to acquaint the child with many of the forms of nature. The work is essentially perceptive — perception of things and the relationships of things. The material is therefore mainly minerals, plants, and animals. The actual presence of the objects in the hands of a common sense teacher is the main factor for success. The aquarium, the vivarium, potted plants, the school garden and the daily phenomena of meteorology supplement excursions which should of course always have first consideration. Expression should be for the most part oral and as informal and conversational as possible. Vividness of presentation should be the means of fixing the knowledge. This part of the work has been well thought out and nature study in its present form and significance is well suited to the primary grades.

In addition to the work along biological lines the calendar lessons of the first three grades makes profitable study. The first of each month is a suitable time. The names of the months and seasons may be taught in the first grade. The number of days in the month, the character of the months, and the character of the seasons may be taught in the second grade. The occupations of the seasons may be considered in the third grade. These lessons may lead to some observations of the sports peculiar to the seasons. Some comparison of the seasonal appearance of plants and animals may well be made. The calendar and the almanac are the text for these lessons, and the weather, flower, bird and insect calendars are excellent applications. The material for study is always available.

The primary colors should be taught in the first grade and the colors applied to the flowers of solid color. The forms of matter: evaporation, clouds, storms, winds, moon's phases, and snowflakes, all make excellent nature study material for the lower grades. There is no more interesting or instructive observation lesson than that of examining the snowflakes and tearing paper snowflakes.

The work of the grammar grades ought to be along two separate lines — one for boys and one for girls — but as this is not possible and there seems to be little tendency toward a condition which will make it possible, I am inclined to favor the boys. The work should be presented in the problem form. The students should be encouraged to suggest as many of the problems as possible and then be allowed to determine the means of working them out. The student should be lead to explain for himself certain phenomena, with which he comes in daily contact, in order that he may come into an understanding relationship with his environment and at the same time increase his ability to solve for himself practical problems (not mathematical). With this end in view, the following points should be made important: (1) The student and not the subject-matter is the first consideration; (2) the subject-matter is to be a means and not an end; (3) the problems are to be solved in the light of the horizon of the student and not that of the research student.

Physical phenomena seem to be the best material for this work. The experiments run through a short period of time and the conditions are easily controlled. Results are definite and many secondary problems suggest themselves. In none of the work should there be any attempt to develop mathematical formulas or *formal* definitions. In considering the pendulum my students of the seventh year worked out the following laws: (1) the weight of the pendulum bob makes no difference in the number of swings of the pendulum in a given time; (2) the length of the swing of the pendulum bob makes no difference in the number of swings of the pendulum in a given time; (3) the shorter the pendulum rod the greater the number of swings of the pendulum in a given time. At the request of the teacher, the students themselves decided what might affect the number of swings, devised the experiments, and finally agreed upon the above as the laws which govern the swinging of the pendulum.

In the eighth year, the present elementary biology, planned for the first year of the high school, with some expansion of the introductory experiments in chemistry, and an elimination of some of the anatomical work, makes an excellent course.

In the *Course of Study and Syllabus for Elementary Schools* published by the New York State Education Department there is an excellent outline for the first five years. The outline for the three upper grades inclines to agriculture almost exclusively. As has already been said, the work should be divided in the upper grades. To go a little farther, it seems as though not only the basis of sex be used but a farther division be made on the basis of chosen profession or trade. The three years' work would then be arranged by courses and subjects rather than by grades. Educators will some day come to realize that, in order to secure the results desired, from the sixth year on, the student must be appealed to in the light of a chosen work, trade or profession. Instead of the present system of grades there then will be an organization of the work in the light of the different professions. The chemical and physical laws taught to an agriculturist will be the same as those taught to a doctor, but the methods, and more especially the illustrations and applications different. Taking the situation as it *is*, the course must be planned without the assurance of a vital interest on the part of the student.

Summary

1 Times are propitious for a general introduction of science study in the elementary schools.

2 Biological material should not be dominant all through the course.

3 There should be some distinction between the lower and higher grades.

4 Nature study for the primary and elementary science for the grammar grades.

5 The ideal course of study for upper grades.

Augustus Klock — It is not my purpose to define specifically a course in science for elementary schools for I think that every teacher will make his own selection of material for such a course — a selection that will depend on local conditions and will consider local industries. Instead, I shall describe an elementary course in science that for seven years has been in successful operation at Beverly with students about 13 years of age.

Any course in elementary science must to my mind possess three primary motives: (1) It must teach the scientific method of work and consider the fundamental concepts and operations of science in general so that it may serve as a good foundation for later science work. (2) It must be presented in such a way as to arouse in students a love for the subject and a desire for more science. (3) The pure science must be correlated with its practical applications so that the pupil may appreciate what science has done and is doing for the comfort and convenience of the race.

The elementary course in science at Beverly is given to students in the ninth year of their school work. The average entering age is 13.7 years which is probably not far from the average age of students in the last year of the New York elementary schools.

This course is essentially a laboratory course in which a careful record of laboratory work is made. It is, in the main, nonmathematical and does not involve formulas and equations for reactions in the chemistry. The year's work is divided into quarters of 10 weeks each. The last week of each quarter is given up to examinations (for this is examination week in all departments of the school), the last week but one to review, leaving 8 weeks of each quarter for new work. We have, moreover, our own little book, published by the school department, which serves as the textbook for the course. This book, as has been implied, contains 32 lessons, each one of which is the particular theme for the week; and while the book contains the more important part of the work of the course, it is understood that each teacher will supplement the book work with a wealth of outside information.

As has been said, there is a particular topic or general theme considered each week. A laboratory experiment performed on Monday, or at the first meeting of the class in any particular week, introduces the subject and gives the student a first-hand acquaintance with his week's work. A thorough discussion of the experiment with a number of questions for study to serve as mental whetstones follows in the second meeting, and the remaining two periods (out of a total of four 50 minute periods each week) cover the descriptive matter and the practical applications.

For example, the theme of work in the twenty-fourth week is a consideration of the methods of purifying water. At the first exercise of that week, the student performs experiments illustrating the purifying of water by distillation, and by filtration. At the next exercise the whole matter is thoroughly discussed and at the succeeding exercises the practical application of these processes for industrial and sanitary purposes is emphasized, as a justification for the pure science work of the first part of the week. Obviously, a consideration of city filtration beds, of brine concentration in the cold countries of the earth, and of the great process of distillation carried on by nature is properly included in these concluding lessons of the week. It is, of course, not always possible to complete the experimental work in a single 50 minute period and, in that event, two periods may be used. Furthermore, inasmuch as there are about 150 people taking the course, involving seven divisions of parallel work, it is not always possible to arrange for a single section to do all of its work in a single period.

To give some idea of the content of the course, the following headings or general themes covering the entire 32 weeks are given. These subjects are obviously inadequate to give any clear idea of the content and mode of presentation of the course in detail.

First quarter

1 The metric system
2 The fundamental units of measurement
3 The subdivisions of matter
4 Properties of matter (general properties)
5 Properties of matter (specific properties)
6 Mechanics of solids
7 "Centrifugal force," center of gravity, center of buoyancy
8 Work and energy

Second quarter

1 The Bunsen burner
2 Effect of air on elements heated in it
3 Change in weight of elements heated in air
4 To separate and identify the substance that unites with metals when they burn
5 Oxygen
6 To find a second gas in air
7 Carbon dioxid (2 weeks)

Third quarter

1 Water vapor — a fourth gas in air
2 The weight of air, atmospheric pressure
3 Energy of heated gases
4 Hydrogen
5 The composition of water
6 Density of water — the thermometer
7 The freezing point of water and its boiling point
8 The methods of purifying water

Fourth quarter

1 The moisture of the atmosphere
2 Storms
3 Ocean currents
4 The heating of buildings, convection
5 Heating by radiation — the graph
6 The ventilation of buildings
7 Pumps
8 Energy of moving water

The more important laboratory experiments involved under the above headings are given here simply according to the object of each experiment.

1 To measure a straight line

2 To find the relations of the hypotenuse of a rightangled triangle to the other two sides

3 To find the relation of the diameter of a circle to its circumference

4 To become familiar with the Bunsen burner

5 To study the effect of heating certain elements in air

6 To find whether iron gains or loses in weight when heated in air

7 To study the effect of heating burned mercury above 370° C.

8 To identify the gaseous product obtained by heating burned mercury

9 To obtain oxygen from potassium chlorate and study the properties of oxygen

10 To determine the percentage of oxygen and of nitrogen in the air

11 To find a third gas in air and study it

12 To continue the study of carbon dioxid

13 (*a*)To find a fourth gas in air, (*b*) to find the use of dust in the air

14 To study the weight of air

[1] * 15 To study (*a*) the cause of air currents, (*b*) windmills, (*c*) hot air engines, (*d*) gas engines

16 To prepare hydrogen and to study it

17 To study the composition of water

18 (*a*) To find the weight of one cubic centimeter of water, (*b*) to become familiar with the thermometer

19 To find the boiling point and the freezing point of water and to note the effect, on each of these points, of substances dissolved in the water

20 To study the methods of purifying water

21 To study the dew-point and the hygrometer

22 To study condensation and rain gage

* 23 To study the cause of ocean currents

* 24 To study the convection of water and gases

* 25 To study radiation and the use of the graph

* 26 To study (*a*) the anemometer, (*b*) the gas meter

* 27 To study pumps and the siphon

* 28 To study waterwheels

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[1] The asterisk * indicates experiments performed by the teacher.

As a result of this course, in addition to the training in and for itself, and the information, students possess after the year's work a knowledge of many things they will meet in later science courses. Among them are a knowledge of the metric system; the ability to measure to the tenth of a millimeter; a knowledge of the operation and use of the Bunsen burner; the ability to read a centigrade thermometer to the tenth of a degree; expression of the results of experiment in graphical form; a knowledge of the methods of manipulation of the commoner forms of physical and chemical apparatus.

I have found it possible, and of decided advantage, to assume a knowledge of these things on the student's part in more advanced courses along the same lines. This is especially valuable in the Beverly High School where there is a five year, nonconflicting science course, the content of which is practically allied to physics and chemistry only.

From a general point of view, it will be seen that this course occupies the first quarter with a study of elementary physics as a ground work for subsequent study. The second quarter introduces the study of elementary chemistry taking the air as its general theme. The more important constituents of the air and their properties are thus made familiar to the student and a good opportunity is offered, also, for the inductive method of teaching. At the beginning of the third quarter, the study of water vapor as a constituent of the atmosphere leads up to the study of water in general, its synthesis, its composition, its density and the larger functions it serves in the atmosphere, on land and in the ocean.

It is obvious that, in this course, in addition to the study of matter in general, the particular substances of air and water, and their mutual action in the larger atmospheric phenomena, are pretty thoroughly studied. Students thus get a course that considers some of the more important fundamental principles of physics, chemistry, physical geography, meteorology and other phases of nature study in such a way that the water-tight compartments of science are, from the first, largely removed.

Brief papers were also read by John F. Woodhull, Teachers College, New York, and by C. Edward Jones, Education Department, Albany.

Tuesday afternoon, December 29

INSPECTION OF LABORATORIES AND APPARATUS EXHIBITS

During the meeting the laboratories in all of the science buildings were open for inspection. At 2 o'clock Tuesday, Prof. R. A. Porter gave demonstrations of " The Measurement of the Force on a Current-bearing Conductor in a Magnetic Field;" and also "A Direct Study of a Falling Body." A special exhibit of apparatus in mechanics and heat was arranged in room 17, Steele Hall of Physics, and of the apparatus for the elementary course in physics in room 27. These exhibits were in charge of Instructors Holbrook and Harris.

In Bowne Hall of Chemistry. Exhibits in room 303 were by Messrs Bratt and Gouldin. The principal experiments of the chemistry syllabus were set up with standard apparatus. Some economical suggestions were also offered. Interesting lecture apparatus, sample laboratory directions for high schools and a representative collection of recent entrance notebooks were shown.

The exhibits in nature study and high school agriculture, together with the various exhibits in biology were in Lyman Hall of Natural History. Many manufacturers and dealers showed interesting exhibits of new or recent apparatus for the various sciences, and the following exhibits were presented by teachers of science:

Nature study and high school agriculture exhibit, by the State College of Agriculture of Cornell University, by M. P. Jones, room 208, Lyman Hall.

Part 1. To show laboratory exercises which may be used in the teaching of agriculture in the high school, following the agricultural syllabus for secondary schools as prepared by the New York State Education Department.

Demonstrations as follows: Types of soil and subsoil; relative productivity of soil and subsoil; depth for planting seeds; plant food and fertilizers; drainage; relation of soil color to soil temperature; per cent of air in soils; warm and cold soils; effect of humus and lime on soil; capillary rise of water in soils; propagation of plants; respiration and transpiration of plants and the formation and translocation of plant food; identification of legumes, cereals and grasses; bacteria and molds; plant diseases; insect enemies; germination of seeds; purity of seeds; grafting, budding and pruning; cattle; balanced rations for cattle; horses; farm forestry.

Part 2. To show work actually accomplished in teaching agriculture in high schools of this State. Laboratory notebooks from Randolph High School, Parker High School, Clarence, N. Y., Deposit High School.

Part 3. To show work which may be done in the teaching of nature study agriculture in the city and rural elementary schools and to show equipment which may be used.

Exhibit to show literature available: Cornell Rural School Leaflets for teachers, sent free to teachers in State by College of Agriculture, Cornell University; Home Nature Study Course for teachers (free); Cornell Rural School Leaflets for boys and girls (free); Traveling Library from the New York State Education Department; Farmers' Bulletins from Department of Agriculture, Washington, D. C. (free); State Experiment Station Bulletins (free).

To show the study of: The Babcock milk test; an animal in the schoolroom, such as a rabbit; poultry in the schoolroom (collections showing types of feathers and their arrangement); an egg; common types of soil; common cereals, grasses, farm crops, flowers and weeds and their seeds; plant diseases; leaves and bark and wood of common trees; birds, insects, animals of the out of doors; birds' nests and insect and animal dwellings; nuts; the United States Weather Bureau map; types of corn, an ear of corn and the way to judge a good ear of corn; the germination test of seeds; fruits and their classification; plant diseases; insect pests; bacteria and molds.

Part 4. Exhibit to show work of farm boys and girls clubs, organized under the direction of the College of Agriculture, Cornell University; school fair exhibit of Sharp Eyes (a farm Boys' and Girls' Club in a rural district school at Seneca, N. Y.); exhibit of weed seeds (Farm Girls' Club, Haviland Hollow School, Patterson, Putnam co., N. Y.); exhibit of tree seeds (Farm Boys' and Girls' Club, district no. 18, Otsego co., N. Y.); exhibit of bark of common trees (Farm Boys' Club, Haviland Hollow School, Patterson, Putnam co., N. Y.).

Part 5. 1800 square feet of exhibit showing nature study agriculture work in elementary grade and rural district schools from the school of Steuben county, N. Y., under direction of Mr H. L. Drummer, Bath, N. Y.

Exhibits in nature study from Andrew Jackson, Belleview, Madison, Danforth and Putnam Schools, Syracuse, room 205, Lyman Hall.

Syracuse kindergarten nature study exhibit, room 205, Lyman Hall.

Biology exhibit, by Misses Hamson and Overacker, Central High School, Syracuse, room 205, Lyman Hall, as follows:

Demonstration of seedlings to show stages of germination; osmosis; digestion of starch; need of air for germination; use of stored food in seeds; effect of light and darkness on growth of roots and stems; response of stems and roots to force of gravity; life history of a frog.

Exhibit of recording tuning fork, for determining the vibration rate of fork. E. R. Smith, North High School, Syracuse. Room 215, Lyman Hall.

Exhibit of home made elementary science apparatus constructed by the pupils of the seventh and eighth grades. The collection, consisting of 23 pieces, came from the 12 schools of Richmond borough, New York city, where science is taught.

Dr John S. Shearer, Cornell University, Ithaca, gave a very interesting and instructive discussion of the gyroscope with demonstrations and showed the application of this principle to mono-rail cars. He described the construction of the Brennan mono-rail gyroscopic car, and demonstrated the ability of this car to travel on a cable suspended across the lecture room.

SECTION MEETINGS

Tuesday afternoon, December 29

Section A — PHYSICS AND CHEMISTRY

IONIZATION THEORY

Demonstration with application to electrolysis

HARRY A. CARPENTER, WEST HIGH SCHOOL, ROCHESTER

It has been known for a long time that the freezing point of a solvent is materially lowered by the solution of some substances and the boiling point of the liquid is raised; but until the study of osmotic pressure and its cause was taken up, the exact quantitative effect of solutes on the points in question was not much considered. Then it was found that the amount of lowering of the freezing point or raising of the boiling point was proportional to the amount of solutes used, and with some organic acids, salts etc., the effect was determined to be proportional to the number of dissolved molecules. According to Kaoult, one molecule of solute to 100 molecules of solvent produces a lowering of the freezing point to .63° largely independent of the nature of the solute, and the raising of the boiling point of liquids is proportional to the number of molecules of solute; also, the osmotic pressure of a solution is proportional to the number of parts of the solute.

This relation seemed to hold good until applied to solutions of some of the minerals, acids and salts. These solutions have a greater osmotic pressure, a greater lowering of the freezing point and greater increase of the boiling point than the dissolved number of molecules would indicate, and, in fact, in dilute solution the amount of change is double the effect produced by the organic materials. With either class of solutes, solutions having the same osmotic pressure have the same freezing points.

Solutions of nearly all substances have some power of conducting the electric current and the conducting power was found to bear a definite relation to the number of dissolved molecules of the organic compounds. As in the case of osmotic pressure so with the conductivity. Dilute solutions of minerals, acids, bases and salts gave double the conductivity deduced from the number of dissolved molecules. All these facts indicate that the effects produced are in proportion to the number of dissolved parts of solute, whether molecules or parts of molecules, and, in as much as in dilute solutions of some compounds the effect is double the effect required by the number of whole molecules, it seems reasonable to assume that each of these molecules under the conditions is broken into two parts.

It is interesting to know that investigators have established the fact that the osmotic pressure — lowering of the freezing point and increase of the boiling point of a solution — is proportional to the number of dissolved parts of the solute and that the effect is, in most cases, independent of the nature of the " part " whether it is a whole molecule or part of a molecule.

Having considered briefly the historical development of some of the facts of solution, how shall we state and develop the theory in order that a high school class in chemistry may get the most for themselves? In order to avoid confusion I think it a good plan to state the theory in two parts and to demonstrate, as far as possible, each part separately.

First, when some substances are dissolved, their molecules are more or less separated into two parts called ions, which are to some extent freely moving bodies in the solvent.

Second, these ions carry charges of positive or negative electricity produced, perhaps, as a result of the tearing apart of the molecule by the energy of solution much as the charges are produced on glass and fur, and the conduction of an electric current through a solution is made possible by these ions migrating toward oppositely charged poles or electrodes. Also, solution of those substances whose molecules do not ionize will not conduct a current.

To prove the first proposition then, let us consider the following facts. Anhydrous copper sulphate is white. White, therefore, must be the color of the copper sulphate molecule and if mixed with flour it would suffer no structural change and would not change the color of the flour. In the same way if we could mix it with water, that is dissolve it in water, without its structure or unity being changed it ought to produce no color change; but the fact is copper sulphate solution is blue. Has there been a structural change? If we dissolve copper nitrate in water the solution is also blue. Anhydrous copper chlorid is yellow, and mixed with flour gives it a yellow tint, but when dissolved in water makes a blue solution which on being heated turns green. The blue color of copper solutions evidently is not due to the color of the molecule. But since all copper salts give a blue solution, regardless of what the acid radical may be, we are led to the conclusion that the color is due to the one constant part, the copper, and this necessarily presupposes a structural change or separation of the molecule into the metal part and the acid radical part.

If we examine solutions of potassium sulphate, potassium nitrate and potassium chlorid we see that they are colorless; hence, it is certain that if these salts separate, the acid radicals do not give color to the solutions, so we must reason that the color of the copper salts in solution is due to the copper part and not to the acid radical part, and as we have seen above, it is not due to the molecule as a whole.

I have said that anhydrous copper chlorid is yellow and its solution in the cold is blue, but if heated turns green. This indicates that in the hot solution some color (yellow) is due to the molecule as a whole and some color (blue) is due to the copper part of the separated or ionized molecules and the resulting color is what we would expect — green. Examination of solutions of nickel salts shows them all to be green, regardless of the acid radical. Solutions of chromium salts are all bluish green.

Water solutions of all cobalt salts are pink. Anhydrous cobalt chlorid is blue; therefore the color of the cobalt chlorid molecule is blue; hence the color of its solution in water is not due to the molecules as units. If a solution of cobalt chlorid could be made so that the salt would not be ionized the color of the solution should be blue. An alcoholic solution of cobalt chlorid is blue and we must conclude that the color is due to the cobalt chlorid molecules as units. Now, if our theory is correct, the addition of water to this blue solution ought to cause the molecules to split up or ionize and give the pink color due to the cobalt part, and such is the fact. Therefore, we must conclude that the energy of solution causes the molecules of some substances to separate more or less into two parts, which Faraday called ions. It must not be concluded that it is always the metallic ion that is colored, for the potassium ion is colorless. It is true that the chromium ion is bluish green, but combined with oxygen in the acid radical of potassium chromate the color of the solution, yellow, is due to the CrO_4, while in solutions of potassium bichromate the color is red due to the Cr_2O_7 ion.

Water has greater power to cause ionization than any other solvent. Methyl alcohol has greater ionization power than ethyl alcohol, in fact ethyl alcohol causes very little ionization. Also, some compounds are more dissociated by solution than others, e. g. in general, minerals, acids, bases and salts dissociate more than organic compounds. In either class those substances that dissociate but little are called weak and those that dissociate readily are called strong.

For our proof that the ions possess charges of electricity it is only necessary to note the action of solutions of dissociated compounds when subjected to the influence of the electric current. First of all let us consider a solution of sodium sulphate. According to the theory when the salt is dissolved in water it is separated into sodium ions and sulphate ions. Sodium in the ordinary metallic or molecular state reacts violently with water with the liberation of hydrogen and the formation of sodium hydroxid. Why, then, if sodium exists as a free body or ion in solution does it not produce the same violent reaction? Evidently it does not; therefore we must conclude that it is at least different in some characteristics from ordinary sodium. If this difference is the possession of a charge of electricity by the sodium ion, then, if that charge could be neutralized or discharged, the sodium ought to act as ordinary sodium and decompose the water. A solution of sodium sulphate is neutral to litmus and is colored violet with litmus. If the solution is placed in a U-Tube and platinum electrodes from a battery placed in the solution at the top of each arm, and a current passed, after a time the solution in the arm containing the positive electrode turns red and the solution in the arm containing the negative pole turns blue. Therefore in the positive arm is produced an acid and in the negative arm is produced an hydroxid. This indicates that the sodium ion is charged positively and the sulphate ion negatively; for if considered from the standpoint of the ionization theory the observed results ought to occur. If we assume a positive charge on the sodium ion and that it is free to move, then on introducing into the solution a sufficiently strongly charged negative electrode we would expect that the sodium ion would migrate to that pole. Here one of two things would happen. The sodium ion if it touched the electrode would have its charge neutralized. It would then, as atomic sodium, react with water and form hydrogen gas and sodium hydroxid. The hydroxid formed would react with the litmus and produce the blue color.

Or, as is more likely, if there were a few molecules of dissociated water, as seems true, then, instead of giving up its charge to the pole, the sodium ion having a higher discharging potential than the hydrogen ion present, takes the place of the hydrogen ion to form dissociated sodium hydroxid while the hydrogen ion from the water gives up its charge to the pole and escapes in the form of a gas. In either case the sodium ion must have been charged to cause it to migrate to the negative pole. In the same manner the sulphate ion would migrate toward the positive pole; there a free hydroxyl ion having a less discharging potential than the sulphate ion, gives up its charge, reacts with water and, after liberating free oxygen and forming water, leaves two hydrogen ions which, with the sulphate ion, forms dissociated sulphuric acid which turns the litmus red.

Also, if the current of electricity is passed through solution of salts of the harder metals, the metallic ion always migrates to the negative pole. For example, if a solution of lead acetate is used, the lead collects at the negative electrode in the form of a tree and if the current is reversed the lead is gradually taken away from the original pole and deposited on the other pole, now the negative. The electrodes being merely extensions of the poles of the battery or generator are charged positively and negatively and the ions being charged bodies and free to move, obey the law of electrostatics. In fact the so called conduction of a current through a solution is made possible only by virtue of these charged bodies or ions. If, for example, a solution of sugar is used we find it will not allow a passage of the current. Moreover, boiling point, freezing point, and osmotic pressure tests show that sugar mixes with water in the molecular form without separation into parts, hence no free ions exist in a sugar solution, and according to our theory ought not to conduct an electric current.

The practical interest is in the relation between ionization and electrolysis. I think it ought to be made clear that, except in a very few cases, ionization precedes and is independent of electrolysis. Electrolysis is the process of sorting the ions to their respective poles and thus making the separation more or less permanent. It must also be kept in mind that, while solution in water, methyl alcohol and other solvents is the most common cause of electrolytic dissociation, heat and, to a limited extent, electrical energy cause electrolytic dissociation, as for example, the fused hydroxids of sodium or potassium. Also, ions of solution may be formed in various ways. They may be the simple molecule ionized into simple ions, complex ions due to the interaction of ions and ions, or ions and molecules.

In conducting an electrolysis the question whether the liberated product is a primary or secondary product is important, as it has been determined that metals deposited as secondary products give a finer grained, more compact, durable, and shiny coating than when the same metal is deposited as a primary product. In most cases the current strength and voltage are the determining factors. In the electrolysis of dilute solutions of strong acids and bases it is probable that the hydrogen and oxygen are primary products. In the electrolysis with a weak current of dilute hydrochloric acid the products are hydrogen and oxygen as primary products due to the slight ionization of water. A stronger current with higher voltage may give some chlorin as a primary product at the positive pole due to the slow ionization of water molecules, while with a weaker current time is given for new molecules of water to dissociate. With concentrated hydrochloric acid and a strong current hydrogen and chlorin are evolved as primary products. In the electrolysis of salts of metals that decompose water, hydrogen and oxygen are liberated as primary products if the current is weak, while with a stronger current and higher voltage the metal is probably deposited first and then reacts with water forming hydrogen as a secondary product. In the electrolysis of water the hydrogen and oxygen are probably primary results. Pure water has a very small conductivity; therefore water is to a very slight extent dissociated into hydrogen cathions and hydroxyl anions. An acid is usually added to increase the conductivity. The acid, sulphuric for example, ionizes into hydrogen cathions and sulphate anions. The cathions of the acid migrate toward the cathode, take the place of the cathions of the ionized water molecules, which have given up their charge to the cathode and separated from the solution as ordinary hydrogen. The sulphate anions migrate toward the anode to take the place of the hydroxyl anions of the water which have given up their charges to the anode and reacted with water to form water and oxygen which is liberated as a gas. In the electrolysis of salts of the harder metals, copper, gold, silver, nickel etc., the anion usually takes the same procedure as the anion of sulphuric acid. The metal cathion is usually deposited as a primary product from simple salts but as a secondary product from double salts, hence the use of double salts in electroplating.

In every case of electrolysis a certain decomposition voltage must be used to cause the ions to migrate and become discharged. In the case of acids, bases and salts of alkali metals, if hydrogen and oxygen are the primary results the decomposition voltage is practically the same and, as we have seen above, it should be so since it is really the decomposition voltage of the dissociated water molecule. In the case of salts of the harder metals the decomposition voltage varies with the cathion and on this fact depends the electrolytic separation of metals. If salts of two metals, A and B, are in solution and if A has a decomposition voltage of 1.7 and B of 1.8 then so long as the current has a voltage more than 1.7 and less than 1.8 only A will be deposited. After A is all deposited the current may be raised a little over 1.8 when B will deposit. If the voltage is more than 1.8 in the first place, both A and B will deposit simultaneously and in a proportion controlled by the current strength and composition of the electrolyte. Advantage is taken of this fact in brass plating, the cathions being copper and zinc. If the voltage is less than the decomposition voltage of that salt in the solution having the lowest value, the current will be interrupted, hence it is evident that a certain amount of electrical energy must be expended to cause a definite migration of ions and a certain potential difference between the ion and electrode must exist to cause the ion to deposit or become discharged.

The use of the theory of ionization in explanation of the action of indicators, neutralization and hydrolysis is important. Litmus is a weak acid and as such is only slightly, if at all, ionized in water. The color of the molecule is red and in the presence of a solution of a strong acid no ionization of the litmus takes place and the color of the mixture of solutions is red due to the red litmus molecule. With a solution of a strong base the weak acid litmus reacts with the base to form a metal salt of the litmus, which dissociates into the metal cathion and litmus anion which is blue. This reaction takes place only if the metal is combined originally with an hydroxyl ion which unites with the hydrogen cathion of the litmus acid to form undissociated water molecules. Litmus can not be used to advantage with weak bases, i. e. those that are slightly dissociated in water, because a salt of a weak base would be formed with the litmus which would hydrolize with water to produce the original condition again to a certain extent and prevent a sharp color change. Practically the same explanation applies to the weak acid phenolphthalein. The following experiment is given by Jones to illustrate the action of indicators. An alcoholic solution of phenolphthalein is colorless since the molecule is colorless and is not dissociated in alcohol. If alcohol is in considerable excess a few drops of strong ammonia may be added without the red color of the anion of a salt of phenolphthalein being evident. The explanation is that ammonia is but slightly dissociated in alcohol, hence the substances, I should say, act as a weak acid and base and no color change is seen. The addition of water will dissociate the ammonium hydroxid when as a strong base it reacts with the phenolphthalein acid to form a dissociated salt of phenolphthalein which has the red ion. This explanation has been contested by Professor Hildebrand of the University of Pennsylvania in the December number, 1908, of the *Journal of the American Chemical Society*. With sodium or potassium hydroxid instead of ammonium hydroxid the color reaction occurs normally since they are dissociated in alcohol. Certain it is that the reactions of indicators are not well understood and furnish good material for investigation.

An acid may be defined as a substance that ionizes in water into an electro-positive hydrogen ion and electro-negative nonmetallic ion; and not as some present day textbooks say that an acid is any substance whose water solution gives free hydrogen ions, for as we shall see a water solution of copper sulphate gives an acid reaction due to hydrolysis. Hence, a distinction should be made between the terms "acid" and "acid reaction." A base is a substance that ionizes in water into an electro-positive ion and electro-negative (OH) hydroxyl. All acids in solution give the hydrogen cathions and all bases in solution give the hydroxyl anions.

Since water is but slightly dissociated, whenever a mixture of solutions is made so that free hydrogen ions and hydroxyl ions are in the same solution they unite to form molecules of undissociated water. Hence, we have the explanation of neutralization; for example,

$$\overset{+}{\text{Na}}\overset{-}{\text{OH}} + \overset{+}{\text{H}}\overset{-}{\text{Cl}} \text{ —— } \overset{+}{\text{Na}}\overset{-}{\text{Cl}} + H_2O \text{ (undissociated)}$$

Therefore the heat of neutralization is really the heat of formation of the hydrogen ion with an hydroxyl ion, and is constant for solutions of all strong acids and bases. Reactions between weak acids and bases depend on the fact that the water molecule is less strongly dissociated than the acid and base molecules; also the heat of neutralization is somewhat less than that of strong acids and bases.

Hydrolysis, the reverse of neutralization, depends upon the fact that weak acids and bases are but slightly dissociated, if at all, in water and that water is dissociated to a slight extent and may be considered either as a weak acid or weak base, HOH. A strong salt of a weak base, for example, copper sulphate, dissociates in water into copper cathions and sulphate anions. If then there are a few dissociated water molecules we have also in solution some hydrogen cathions and hydroxyl anions. But copper hydroxid is a weak base, therefore some of the copper cathions unite with the few hydroxyl anions of the water to form undissociated copper hydroxid, thus:

$$\overset{+\ -}{CuSO_4} + \overset{+\ -}{2HOH} —— \overset{+\ -}{H_2SO_4} + Cu(OH)_2 \text{ (undissociated)}$$

which leaves an excess of a few hydrogen ions and these give the acid reaction. Likewise with strong salts of weak acids, some of the anions of the salt unite with the few hydrogen ions of the dissociated water to form a few molecules of undissociated acid. For example, sodium carbonate is a strong salt of the weak acid carbonic, and the reaction may be represented thus:

$$\overset{+\ -}{Na_2CO_3} + \overset{+\ -}{2HOH} —— \overset{+\ -}{2NaOH} + H_2CO_3 \text{ (undissociated)}$$

This leaves an excess of a few hydroxyl ions which give the alkaline reaction. Copper and zinc form weak bases; hence, solutions of salts of copper and zinc give acid instead of neutral reactions. Sodium carbonate and potassium cyanide form weak acids; hence, solutions of their salts give alkaline reactions.

Some interesting facts in connection with the theory of ionization I can only mention. It ought to be understood that the term ionization is not synonymous with the term dissociation, but with the phrase electrolytic dissociation, which means that the dissociated parts are charged, while the term dissociation refers to a separation into parts that are not considered to be electrically charged.

The electrostatic charge on a gram equivalent ion is 96500 Coulombs and shows why ions can not be separated by asmosis as can the products of ordinary dissociation.

Chemical action seems to be most rapid between ions, hence strong acids, bases and salts are more active chemically than the weak, i. e. organic substances. It is even claimed and on good evidence that chemical action can only take place after ionization and only so fast as ions are formed.

Dry sulphur or phosphorus will not burn in dry oxygen.

Dry sulphuric acid and hydrochloric acid have no action on litmus and will not react with dry carbonates.

Dry ammonium gas and dry hydrochloric acid will not react.

Dry hydrogen and oxygen will not unite even at a temperature of 500°C.

The catalytic action of acids in causing inversion of cane sugar seems to be due only to the hydrogen ion.

The florescence of solutions is probably due to dissociations.

The theory of ionization is far-reaching and offers great possibilities to the investigator.

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Outline of method and chemicals

Chemical	Color of anhydrous salt, i. e. molecule	Color of water solution due to ions	Other characteristics
Copper sulphate	White	Blue	
" chlorid	Yellow	Blue	Hot solution green
" nitrate		Blue	
Nickel sulphate		Green	
" chlorid		Green	
Chromium sulphate		Bluish green	
Potassium chromate		Yellow	Due to anion CrO_4
Potassium bichromate		Red	" Cr_2O_7
Cobalt nitrate		Pink	
" chlorid	Blue	Pink	Alcoholic solution blue
Phenolphthalein in alcohol			
Con. ammonia			
Diluted solution lead acetate			

A METHOD AND APPARATUS FOR DETECTING AND EXHIBITING THE FLUORESCENCE OF FLUORESCENT SUBSTANCES

WALLACE GOOLD LEVISON, BROOKLYN

Read in the author's absence by the chairman of the section

On November 16, 1903, I read a paper on "Fluorescent Gems" before the New York Academy of Sciences of which an abstract with several misquotations and errors was published in *Science* [n. s. v. XVIII, no. 468, p. 789-90, Dec. 18, 1903] and a corrected abstract in *Annals of the New York Academy of Science* [v. 15, pt II, p. 202-3, Nov. 16, 1903].

In that paper I showed that many gems are strongly fluorescent and that this property may enhance or depreciate their beauty or efficiency according to circumstances therein detailed. Thus in brief, in the case of colored gems, if the fluorescent color is the same as the natural color of the mineral it tends to enhance its intensity while if it be complementary to the natural color of the mineral it tends to extinguish it and so impair its beauty. Also that white fluorescent gems such as diamonds may have their beauty somewhat impaired by the turbidity or milky opalescence which is an accompaniment of this property. Also that by means of this property or its absence gems may be distinguished from each other and from their imitations since the latter usually differ from the genuine minerals in their response to the exciting rays. In concluding the paper I suggested that the results of the investigation it recorded indicated the possible application of this property as a convenient method of examining and testing gems.

In the discussion which followed it was objected that the methods and apparatus then available for exhibiting fluorescence were so cumbrous that they could hardly be applied in competition with the ordinary time-honored method for distinguishing gems from each other and from their imitations.

In that paper I did not refer to the apparatus I employed for the investigation as it was the subject of an application for a patent. This having been issued after an unavoidably long delay it is the purpose of this paper to briefly describe the apparatus which appears to be sufficiently convenient for practical application, not only for the purpose of testing gems as described in the paper referred to, but also as a laboratory apparatus applicable for other purposes as for distinguishing between dyes in dress goods, detecting adulteration in many cases as of mineral in fixed oils, fluorescent aniline dyes in preserves, and other commercial products.

This apparatus consists of a case somewhat similar to an X-ray fluorescope and which serves as a portable dark room. It has a window upon one side covered by a ray filter of such a color as to transmit only pure blue and some ultra violet light. An ideal ray filter for this purpose has yet to be found. The most conveniently available at present is a flat bottle or cell with polished sides containing a solution of ammonio-sulphate of copper. A section of the case forming a side extension supports a lens 5 inches in diameter opposite the blue ray filter at a distance of about 7 inches, and this lens which may be the front lens of a triple lantern condenser condenses a beam of parallel rays of light such as sunlight or a beam of parallel rays from an arc light lantern to a focus about in the middle of the case through the blue ray filter. Opposite the ray filter is an opening provided with a sleeve of opaque flexible material through which the hand holding a specimen to be examined may be inserted and the specimens held in the focus of blue light.

The specimen is then observed through the small end of the case which is provided with an eye shield with a chenille edging to exclude diffuse light. Within the eye shield is a ray filter or screen of a color which appears yellow and arrests blue and violet but transmits red, orange, yellow, yellow green and green. This may be removed at pleasure. When a fluorescent substance is held in the focus of blue light within the apparatus and its fluorescence thus excited, it usually evolves red, orange, yellow, yellow green or green, but its fluorescent color is masked by the excess of blue light it incidentally reflects. It is the object of the yellow eye screen to cut off or arrest this reflected blue light but to transmit the fluorescent light generated by the material. It is evident that materials which afford only a blue fluorescence (excited by the ultra violet waves) can not be shown with the blue ray filter because they appear practically black, but (as the great majority of fluorescent materials transform or step down the exciting blue, violet and ultra violet light to red, orange, yellow, yellow green, or green) this is of little consequence.

A blue fluorescence can only be detected by examining the substance in the upper range of a spectrum or in the light from a Geissler tube or a spark gap lamp in which the exciting rays greatly predominate over those of lower refrangibility which tend to mask the effect produced.

To permit the examination of such substances with this apparatus a spark gap lamp adapted to fit in the place of the blue ray filter may be provided. Only a limited number of fluorescent substances are excited by the spark gap lamp. Nearly all of these and most of the remainder are excited by sunlight. A few are excited by x-rays and becquerel rays.

WIRELESS TELEGRAPHY

Lecture and demonstration with every point illustrated by apparatus

CHAIRMAN C. L. HARRINGTON, INSTITUTE OF ARTS AND SCIENCES, BROOKLYN

(Abstract)

To illustrate the kind of lecture which is acceptable to the general public of New York city this lecture was given by Charles L. Harrington by request.

In discussing wireless telegraphy attention must be paid to three essentials — something to cause a wireless wave, something to transmit the wave and something to detect the wave. That which causes the wave is the oscillatory spark of the Holtz machine, or of an induction coil worked in connection with a condenser. The spark causes a disturbance in the ether. This disturbance is in the nature of a wave and the wave is of the same nature as a light wave. Some proofs of this statement are that the electro-magnetic wave may be refracted or reflected to pass through solids and liquids acting in all these respects just as light waves act. To prove this we pass electro-magnetic waves which are formed in a copper box through the ether to a second copper box on the outside of which there is what is called a coherer. By interposing glass, water, leather, wood, bricks, stones, copper sheet, zinc sheet or any other solid or liquid we find that the substance which ordinarily transmits light will transmit the electro-magnetic wave. By directing the wave away from the coherer we may by means of a sheet of copper reflect the wave so that it will strike the coherer, the coherer being in all these cases the detector of the wave. By throwing the wave in such direction that it will move to one side of the coherer, and interposing a triangular prism of paraffin, the wave is refracted in such directions as to strike the coherer. Now all these things tend to prove that electro-magnetic waves are similar to light waves. Another proof of this similarity is the interposition of wire screens between the spark gap and the coherer. If a wire screen, with fine parallel vertical copper wires about one quarter of an inch apart, be interposed the waves will pass. If the screen be made of horizontal, instead of vertical copper wires, the waves will pass, but if two screens be placed together so that the two sets of wires are perpendicular to each other, thus practically forming a mesh, the waves will not pass. Now we know that light waves will be acted upon by thin pieces of tourmalin crystals in exactly the same way.

The coherer is a glass tube of small bore having a brass wire extending into each end, first placing in the center of the tube a few soft steel filings and then pushing the brass wires together until they are about one sixteenth of an inch apart. If one of the brass wires be connected through a battery with one pole of an electric bell. and the other brass wire be connected with the second pole of an electric bell no current will pass because the steel filings are not in contact, but whenever a wireless wave strikes the steel filings they become magnetic, and then lie closely enough together to allow of the passage of the current, and the bell will be rung. On gently striking this glass tube with a piece of pencil the steel filings will be decohered and the bell will of course stop ringing. Any wireless wave striking against this tube will cause the action just mentioned. Putting all of this into a practical form it is found that the wireless waves may be carried several feet. If it is desired to cover longer distances then one of the poles of the induction coil should be connected with a wire mast and the other with the ground. Similarly one of the brass wires of the coherer should be connected with a wire mast and the other with the ground. By making the apparatus of suitable delicacy and the masts of sufficient hight and the spark of the coil of sufficient volume it is found that messages may be sent to a distance of from 1500 to 2000 miles.

Section B — BIOLOGY

DEMONSTRATION OF THE WORK ON TYPES IN THE FIRST YEAR COURSE IN BIOLOGY

UNDER THE DIRECTION OF W. M. SMALLWOOD, SYRACUSE UNIVERSITY

Making and Use of Charts. Miss Joslyn
Study of Blood. Miss Smith
Injection of a Frog. Mr Lilyestrand, Instructor, Syracuse University
Explanation of Osmosis. Miss Smith
Plant Physiology — Root Pressure; Transpiration; Respiration of Germinating Plants; Connection between Tracheae of Petiole and Stomata of Blade. G. A. Bailey, Geneseo Normal Schoo
Paramoecium Culture. W. M. Smallwood
Stem Sectioning, Staining etc. Misses Smith and Joslyn

ROUND TABLE CONFERENCE ON THE SUBJECT-MATTER OF THE SYLLABUS

This was a general discussion concerning the methods of teaching biology.

Section C — EARTH SCIENCE

RELATIVE INSOLATION DEMONSTRATION

FRANK L. BRYANT, ERASMUS HALL HIGH SCHOOL, BROOKLYN

A demonstration of the following proposition was made by the use of the B–K solar calculator.[1] By cutting out cardboard sheets of different colors, red to represent maximum insolation, blue, minimum insolation and gray, average insolation received at any latitude and superimposing one upon any other the demonstration is made evident.

(1) At the latitude of New York city, 41° north, about three fourths as much heat is received for the year as at the equator. (2) During the half of the year when the sun's rays are vertical north of the equator, latitude 25° north receives more heat than the equator during that time. (3) During the three months centering about June 21, latitude 41° north receives more heat than the equator during that time. (4) During a period of about 50 days centering about June 21, the north pole receives more heat than any other part of the earth.

The long insolation period in the higher latitudes more than offsets the smaller angle of insolation.

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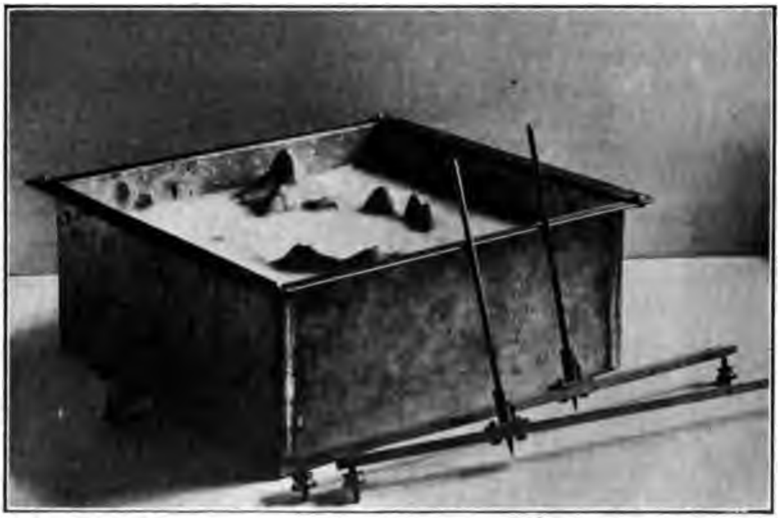
[1] The B-K Solar Calculator is manufactured by the L. E. Knott Apparatus Co., Boston, Mass.

A DEMONSTRATION OF A MAP AND MODELING APPARATUS

I. D. SCOTT, UNIVERSITY OF MICHIGAN, ANN ARBOR, MICHIGAN

The United States Geological Survey has undertaken to survey the entire territory of the United States, an area of some three million square miles, and, according to the Director's Report for 1909, about one third has already been completed. The method of expressing relief used on the maps is the surface contour, and so, if this great reference library is to be at the command of the student of physiography, it is absolutely essential that he have a proper conception of a contour in order to read and interpret these maps. The importance of these maps to the student was early recognized, and several atlases of physiographic types were issued by the Survey. Recently a publication [Professional Paper 60] on "The Interpretation of Topographic Maps" has appeared.



In shaping the laboratory work for the classes in elementary geology and physiography it was thought that, if the student could actually make a map with simple apparatus, using the same general methods that hold in field work, and then check the contours by water levels, he would not only get an adequate conception of contours but also of scale and some idea of the methods used in map making — a process the essentials of which many teachers do not know.

The following apparatus [*see* cut above] was devised by Prof. W. H.

Hobbs.[1] It consists of a galvanized iron tank 12 inches square and 5 inches deep with a flange around the top. Near the bottom is a faucet by which water may be drawn off to within ½ inch of the bottom. Any required depth may be obtained from a vertical scale on the inside of the tank. On the two opposite flanges at the top are fitted scales graduated to quarter inches upon which rest the sliding track and altitude gage.

The sliding track consists of two square brass rods one fourth inch in cross section held at the ends ¼ inch apart, so that there is a free sliding space between them the full length of the tank. This track projects over the outer edges of the flange and may be clamped by a thumb screw in any desired position, provided it be kept parallel to the other sides of the tank. The sliding track is also graduated to quarter inches.

In the space between the rods of the sliding track is fitted the altitude gage, which consists of a slide and a rod. The rod is held in position by a spring clamp and is graduated to quarter inches, but here the unit is ½ inch instead of 1 inch, making the natural contour interval ½ inch.

By means of the scales on the tank and on the sliding track any point on a model within the tank may be located and its altitude above the bottom of the tank taken with the altitude gage. It would probably be advantageous with younger pupils to make the process somewhat mechanical by having them take altitudes at stated intervals, but always keeping in mind that the more irregular the surface, the greater is the number of readings necessary. To illustrate, set the sliding track successively at intervals of 1 inch along the flange, and at each interval take readings across the model. Here the frequency of the readings would depend on the character of the surface covered — even slopes and flat surfaces requiring less frequent readings than the steeper and more uneven surfaces. If the summits of hills and lowest points of depressions are not included, it should be set for each of these separately.

By taking altitudes over the entire model and plotting them directly on cross section paper, the data are at hand for drawing the contours. These are drawn by approximation where the actual hights of the contours do not appear. It is advisable to make the map smaller than the model thus bringing in the scale.

Many will feel that the time required, about three hours, can not well be afforded for a single exercise in a course already well filled. Nevertheless we feel that the interpretation of topographic maps should form the basis of a large part of the laboratory work in physical geography. Facility in map reading is largely a matter of practice, and the more quickly and thoroughly the technic is mastered the sooner will the pupil get to the real purpose of the study, the interpretation of maps. It is our experience that this exercise gains time in the end and we feel that it may profitably be used in secondary schools.

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[1] *See* Journal of Geography, v. VII, no. 5, January 1909.

GENERAL MEETING

The meeting was called to order by Pres. O. C. Kenyon, who spoke as follows:

I wish to thank Principal Hodge for consenting to this meeting, and to say that the Science Association feels highly honored in holding a joint session with the Associated Academic Principals for the discussion of subjects of especial interest to us.

No other class of teachers except that of manual training is so dependent as we upon proper conditions and material equipment. Without sufficient apparatus and supplies, without ample time for laboratory work, sufficiently small classes and not many of them, we can not hope to obtain results equal to those of other teachers. This is because of our especial aim and duty, as I understand it, which is to bring every pupil into direct contact with the thing itself that he is studying; then, to know that he observes for himself, infers from his own observations, and expresses himself, with a fair degree of accuracy and clearness. These results, owing to the fact that no two objects in nature — no two combinations of conditions or circumstances — and hardly any two pieces of apparatus, are exactly alike, can be secured only by individual laboratory teaching; and the farther we depart from strictly individual methods, the less we know, speaking from the science teacher's special viewpoint, what the results are.

Some of the effects may be valuable, but if the pupil has, by his laboratory training, learned to look lightly upon the facts, or to accept his facts from his neighbor, or worst of all, to alter his observations to agree with the conclusion as he knows it should be, then the result for that pupil is deplorable, and he might much better have omitted his laboratory work. But the time required for this careful individual instruction, and for keeping a laboratory in good working order for it, is much greater than is understood by those who have not done exactly these things.

For the Science Association, I may say that from the beginning it has favored thorough, honest, individual laboratory methods, and has sought, in various ways, to extend this method throughout the State. We are aware that our best friends and advisers are, for different reasons, the college faculties in science, the principals of our schools, and the Education Department of the State, representatives of all of whom we have here today. They will no doubt give us good suggestions as to how to improve our science teaching.

EQUIPMENT, CONDITIONS AND METHODS IN SCIENCE TEACHING IN SECONDARY SCHOOLS

PRIN. CHARLES F. HARPER, CENTRAL HIGH SCHOOL, SYRACUSE

(The secretary was unable to obtain a copy of this paper.)

The paper was discussed briefly by Frank Rollins, Second Assistant Commissioner of Education, Albany, N. Y., and by Howard Lyon, Oneonta Normal School.

Mr Lyon said in part — I have been much interested in the paper presented this afternoon. I am led to make a plea for the teacher of science that consideration may be shown him because of the exaction upon his time and energy. Much time is required for the preparation of classroom experiments and for trying out the experiments which students are to perform that the teacher may know what degree of accuracy to expect. Besides the work involved in the adjustment and repair of apparatus and laboratory supervision, the teacher of science must give as much time as the teacher of any other department to the work of review of books and papers.

I have in mind a so called teacher of science in a high school in this State who teaches three classes in English and two in history besides the classes in physics and biology. An impulse to be faithful on the part of such a teacher must be a source of torment, for she must constantly feel the insufficiency of attention to the detail of her work especially as applied to science. With reasonable allotment of time and with an equipment consisting of some standard instruments and further of materials and tools, the teacher of physics may add materially to his laboratory outfit of useful appliances. To illustrate, I have found that a barometer which I have been able to construct with 60 cents worth of materials exceeds in accuracy a standard instrument for which our school paid $30.

It has seemed to me, as I have observed the results of science teaching, that there has been lacking in that particular field of study in our schools what I may call a spirit of fortitude both on the part of students in undertaking such study, and on the part of principals in providing for such work. Students enter the normal school with conditions, largely in science. Such students avoided as far as possible in the high school science subjects and in our school still feel that there must be some other way to graduation than by the mastery of science work.

It has been my pleasure to see numberless cases of inapt students of science, when held rigidly to requirements, take hold of the work and make a marked success, in fact, become the best students of the class. There has come with such mastery an entire change in the individual, a look of confidence and spirit and a brightening of eye which attends success in life in general.

As science presents rather unusual difficulties, it seems to me that a spirit of firmness in the matter of holding students to science work on the part of principals of secondary schools might result in a far stronger body of graduates, and a better preparation for life's work in any field.

Wednesday morning, December 30

Section A — PHYSICS AND CHEMISTRY

THE CHEMIST VERSUS THE TRAINED WORKMAN

R. LIVINGSTON FERNBACH, BROOKLYN

Science Teachers of the Empire State: You are assembled in annual conclave for the interchange and comparison of ideas relative to the scientific instruction of the youth of the State. Responsible in large measure for the stimulation and direction of the effort of our future citizens, not only in training them in the way they should go as citizens, but, in many instances laying the foundation for a future calling and life work, yours is indeed no sinecure. As members of the aristocracy of intellect, the sole aristocracy to which the rightly guided youth of this nation should aspire, to those who come under your instruction you constitute the highest court of appeal. Your dicta are the foundation stones of the intellectual structure. "As the twig is bent, so is the tree inclined." How bitter, then, that the structure, erected by you with infinite patience, must in after years be razed to the ground and the contour of each stone of theory be modified in the light of practice.

The trend of the times is toward educational anarchy. We are about to experience a reversion to old methods and old standards. Today, our educational institutions fail of their very function. They do not educate. They simply teach. They do not give that severe abstract mental training which of itself is sufficient for the intelligent acquirement of further learning. They merely inculcate that little knowledge which is a dangerous thing. The principle of the church sociable is adopted. A veritable hodgepodge of subjects is carefully concealed in a bag. Let the student shut his eyes, thrust in his arm and consider at leisure what he has drawn. First prize? Truly, the young man was gifted with discernment beyond his years! Booby? Then did the young man fail to take proper advantage of his educational opportunities: nothing left to the imagination; nothing to the natural elements of virgin mental soil!

If this condition obtain in our universities, the highest courts of learning, what shall we say of our secondary schools which today have lost sight entirely of their proper functions and more and more usurp the scope of the university. ~~Yes~~, I know what you would say. " Many a youth can go only through the high school. The doors of the university are barred to him for salient reasons.

Accordingly, we must teach him as much as possible in the high school." You stand condemned because of this very altruism. If the development of the student in the scondary school, if his apperception be sufficiently keen for the inculcation of a smattering of a multitude of subjects, what need of the university? Why not merely the primary and then the secondary school?

A great man has said, "The well educated man knows something of everything and everything of something." Impressed with the neatness of the epigram, we proceed to teach something of everything but, alas! not everything of something. Hark now to the cry of the opposition! "To teach a man everything of something is to make him weak, one-sided, special. You bar him from intelligent intercourse with his fellows." It is a far cry, ladies and gentlemen, from pedagogy to household furniture. Apologizing for the digression, I would ask you to picture in your mind's eye the heirloom, the sturdy piece of mahogany. Homely, I grant you, but genuine, solid, true. No bright polish characterizes it. Yet is there a place in the household where it will not accord with esthetic fitness? Contrast with this the modern piece of furniture. At heart, white pine, a worthy wood of its humble class. On its surface, a deep red stain, partly hidden by a brilliant veneer. Time must dull this, revealing the crude wood beneath. The marks of age serve but to enhance the beauty of the genuine mahogany. In the old mahogany you have the product of old educational methods; in the imitation, the product of present systems.

What has this to do, you ask, with the chemist as against the trained workman? Have we come here to listen to an uncalled for arraignment of our methods, methods which receive the sanction of the greatest exponents of pedagogy? I pray you be patient. A little more, and I come to the crux of my thesis. I repeat that we have lost sight of the true function of school training, which is to teach the young how to think, and not to crowd the youthful mind with a multitude of facts to be retained parrot-wise. To this end we select subjects, the laws of which are eternal and immutable, not arbitrary — mathematics, for example, and languages. Give a boy of ten a working knowledge of Latin and you have trained his mind to a flattering degree of receptiveness for other material, the inculcation of which may draw somewhat upon his imagination. The boy starts in the primary school. By the time he reaches the secondary or high school, we can justly extend the material for mental training. Thus, we teach the higher mathematics; we extend the scope of language courses. The teaching of science in any shape, form or degree in our high schools, except so far as concerns an elementary exposition of principles, is to my mind the greatest farce in existence, for the reason that science is not exact; it is empirical. Like a railway time table, it is subject to change without notice. Teaching science does not train the mind. Its proper inculcation presupposes an already trained mentality. I am aware that my views on the teaching of science in secondary schools do not carry the weight of authority. Those whose word is law in these matters have decreed the teaching of chemistry and physics to youths with half baked mentality. I would urge one plea, however. If you must be unwilling participants in what is nothing more or less than a confidence game, at least do not carry your crime to the extent of telling those under your charge that what you are teaching them will qualify them to go out into the world and distinguish themselves. Such is far from the truth; the greater probability is that you merely qualify them to go out in the world and extinguish themselves. I myself am the product of the school, the college and the university. My experience, which is the experience of thousands, has taught me that, in order to convert what I learned at school into a means of livelihood I had to forget it and learn anew in the light of practice. To illustrate my exact meaning, I have chosen the theme of the chemist versus the skilled workman — rule of thumb versus science.

In the development of any science, we are prone to commit the glaring logical fallacy of *post hoc, ergo propter hoc.* We fail to realize that the scientific syllogism is in reality an argument, not from premises to conclusion, but from conclusion to premises. We argue that all practice must have a scientific foundation. We forget that our true scientific foundation is possible only because of practice. The great Newton argued that there must be a law of gravitation and that, because of this law, things must fall to earth. He did not, after formulating an abstract theory, go outdoors and see if things fell in accordance with his theory and then quarrel with them and impugn the entire scheme of nature because they did not. He observed, first, that things were prone to fall to earth unless securely supported, all this assuming that they were heavier than air. He then proceeded to enunciate his immortal theory. He committed no fallacies of argument. It is narrated that, as a boy, he experimented with an earthenware basin, resting this on the flimsy support of the atmosphere of an English spring evening, leaning from a third story window the while. The inevitable happened. Discovered in the act of gathering up the fragments, the application of the maternal slipper speedily followed. In the light of modern science, he would have been justified in believing that his experiment embodied no lesson other than the fact that a spanking and a broken basin were closely interlinked. *Post hoc, ergo propter hoc.* He might have gone further and experimented with a second basin and, because a second chastisement did not follow, quarrel with this fact rather than alter his theory.

We take a student at the university or even at the high school and we say to him, " These are the laws of chemistry and physics. Upon these are dependent certain everyday phenomena. Upon their extension depend the great manufacturing processes. Commit these principles faithfully to memory. You are then qualified to go forth and achieve. Because of your faithful attention to our teachings you have the advantage of your untrained brother in that you are prepared to act in any emergency. You are armed with the invincible weapon of scientific knowledge."

What rank hypocrites we are! We do not say to the student, these are but theories. Many phenomena are satisfactorily explained through them, but many remain unexplained. Chemistry is not an exact science, far from it. Its whole system is arbitrary and may be changed any day in the light of further experience. All we can do and have done is to give you a comprehensive idea of how these things might be accounted for. Just as it is possible for the musician to give more than one interpretation to a sonata or a symphony, so is it possible to interpret scientific data in more than one way.

Accordingly, our student goes forth with the idea that he is equal to any occasion; that all he has to do is to apply his theoretical training. He has reached the stage when he must convert his " knowledge "— God save the mark! — into the wherewithal to live, into bread and butter. He seeks a position in which he hopes to apply his learning. What does he learn? First, that his services are commercially worth less than those of an ignorant bricklayer, because they are not practical. Second, that the man who has never been to college, but who began practical work at an early age is now occuping a position with emoluments beyond the reach of our college bred youth, until he has spent a longer term of years than he gave to the acquirement of theory, to the acquirement of useful, practical knowledge.

Now, your trained workman, uneducated, but drawing better pay than your chemist can hope to draw for many years, is burdened with no nice theoretical arguments or distinctions. He regards only the evidence of his eyes. He knows how to produce a desired result, albeit ignorant of why certain procedure results in this particular way. He has never dreamed of the periodic recurrence of the elements, of the laws of Boyle and Mariott, of the ionic dissociation of the elements. Despite all this, to use a vulgarism, he can deliver the goods. And that is what his employer is concerned with. What cares the average hard headed man of business save for results, practical results?

Now, mark you, Ladies and Gentlemen! Our educational system of today is the result of a desire to inculcate that which will be of some practical service to the student in his battle for existence. In the endeavor to assist him to a means of livelihood, you have no time for the homely essentials which characterize our genuine mahogany. In order that he may appear, at least, to be a finished product, you dip the student into a tub of stain and then polish him off with a cloth until he shines. Every June you clap your hands in glee and exclaim proudly, "Behold the aggregation of brilliance!" Comes the skeptic with the query, "Will they wear?" But you are so busy preparing another batch of half grown humanity for the dipping that you have no time to answer.

Do not say in your pride that, had it not been for scientific training, none of the great discoveries, characterizing epochs in our industrial development could ever have been made. That is nonsense. All of our great discoveries have resulted from very accident. Perkin discovered his Mauve accidentally. He was trying to synthesize quinine. As a result of this accident we have the great aniline industry. Goodyear, seeking to vulcanize rubber, accidentally upset some sulphur into an experimental batch. He left the laboratory in disgust only to return next morning to learn that accident had done what years of research had failed to do. So with the discovery of sacharrin, etc.

I well know that the school and the university can not become factories illustrative of the many industries for the special training of students; that, at best, you can merely lay a scientific foundation. Your whole foundation is false, however, because your premises are radically wrong. The high schools today, because of abortive methods of teaching science, because of the fact that to propound scientific theory to the mentally immature is literally to cast pearls before swine, are responsible for the horde of wage seekers in specialized callings who are neither flesh nor fowl nor good red herring. The absurdity of sending out youths crammed with a false notion of dissociation who can not write intelligent English! If I had my way, chemistry would form no part of the high school curriculum. Physics? Yes. For here we have something tangible for the embryo mind to grasp and assimilate. Principles which are, in a sense, exact. Principles which admit of a mathematical interpretation. Principles which admit of a satisfactory and concrete illustration. But as for chemistry, as she is taught in our high schools and many of our colleges, ye gods!

Teachers, do you not realize that chemistry is like law in that its principles are purely arbitrary and depend for successful application upon their proper interpretation? Do you not realize the futility of telling your students that, because they have listened to you for three or four years, they are not chemists? Analysts, mere mechanical analysts they may be. Chemists, never, unless they possess the Heaven-sent faculty of interpretation. I have taught boys of 16, who have never gone beyond the grammar school, to become expert analysts. I could not hope to teach them to become chemists. You must not discount the personal equation.

While our industrial schools, on the one hand, are turning out specialists without a general education, our high schools are turning out incompetents. Johnnie can not do a sum in algebra but he can talk profusely if inaccurately on the Silurian age. He has a vague notion that Milton played on a winning baseball team but he surely can sew buttons and do tatting.

Shoemaker, stick to your last. If you will concern yourselves with giving a purely general groundwork with a view to teaching the young idea to think properly, let nature and the university do the rest. When you let a boy go from the high school with the idea that he knows enough chemistry to do without the need of further special training and that all he has to do to win fame and fortune is to apply what you have taught him, you are guilty of a crime and nothing less. When a university or college lets its graduates depart with the same notion, having accepted fees for four years, it is guilty of taking money under false pretenses. That very boy or young man will soon appreciate the scurvy trick that you have played him, and when the time comes for his hopeful offspring to broach ideas of a higher education, he will say him nay in the light of mature experience. He will point to the various school curricula and say " My son, to you this means the acme of opportunity. To me it is bunco. To you, you have but to enter the portals to be the recipient of intellectual alms. Be warned. 'Beware false Greeks bearing gifts.' "

DEMONSTRATION OF PHYSICAL APPARATUS

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After an experience of many years in the teaching of physics I have arrived at certain conclusions, which may be best presented in answers to the following questions:

1 Where in the curriculum of scientific study does that of physics belong?

2 How should the subject be taught to arouse enthusiasm and secure practical benefits?

3 How should recitations, written reviews and examinations be conducted?

4 What amount of time should be devoted to laboratory work and what should be the nature of the work?

5 Of what use are practical problems and to what extent are they to be employed?

6 What has been the occasion of the decline in interest in the study of physics and what can be done for its revival?

In answer to the first question: Where in the curriculum of scientific study does that of physics belong? In this curriculum are included physics, chemistry, physiology and hygiene, botany, zoology, geology, physical geography and astronomy. Physics and chemistry are the foundation studies on which the remaining subjects are to be built as the superstructure. Such an arrangement will economize the time of the students and the teacher. As an illustration, I would call your attention to the study of human physiology. This subject treats of the functions of the organs of the human body. The organs of locomotion, the bones with their associated muscles, are beautiful examples of the action of levers. The process of respiration is mechanical and chemical. The composition of the food implies a knowledge of chemistry. The processes of mastication, digestion, assimiliation, secretion and excretion are not clearly understood without an elementary knowledge of these foundation subjects. An understanding of the action of the nervous system and nerve centers is greatly aided by a knowledge of electrical analogies. The structure and function of the eye are understood more clearly if the student has a knowledge of the subject of light and the action of lenses. The proper understanding of the sense of hearing implies a knowledge of the subject of sound. Nothwithstanding these facts, physiology is often the first of the sciences to be taught. As taught in the elementary schools, with relation to hygiene and the deleterious influences of stimulants and narcotics we are all doubtless in accord. When however the subject is taken up in the high school it should be from the scientific standpoint. This is impossible without a knowledge of physics and chemistry. In like manner it may be clearly shown that in the teaching and the acquiring of the other sciences that physics and chemistry are the foundation sciences.

Of the two sciences, physics and chemistry, which should be studied first? The study of physics taxes the mental faculties, memory, reason and judgment; while that of chemistry largely the power of memory. For this fact chemistry may be regarded as the easier study. On the other hand, physics treats of phenomena that are usually apparent and chemistry of those more obscure. Taking all things into consideration it has been my custom to place physics first in the order of study. This I did for a period of 18 years in the schools in which I had supervision of the scientific department.

The pupils entering the high school have a knowledge of mathematics and sufficient maturity of mind to take up the study understandingly. The following has been found to be a successful order in the arrangement of the sciences of the high school curriculum — physics, chemistry, physiology and hygiene, botany, zoology, physical geography, geology and astronomy. The intellectual momentum acquired by the students in this order will carry them onward from subject to subject.

Second question: How should physics be taught, to arouse enthusiasm and secure practical benefits? It is of fundamental importance that the economical use of the time of the students be taken into account, consistent with their health and mental well being. This is accomplished by the teacher being the first and real instructor. The following is an outline of procedure that I have found most interesting and profitable to the students: Select a good textbook; follow the order of topics as a rule; assign no lessons to be learned in advance of the teacher's instruction; the students get their information, first-hand, from the teacher who clearly explains and fully experimentally illustrates the topics under consideration not in formal lectures but in plain descriptive language setting forth facts from which the students may deduce fundamental principles and laws. It is always of interest to them to be placed in the position of original investigators so far as is possible. It is a good plan not to tell them anything that they ought to deduce from what they have heard and seen as presented by their instructor. As a rule by this method the students learn their lessons in the classroom and but little time has to be devoted to the textbook for the recitation that is to follow the next day. It is an old familiar maxim that "there is no royal road to learning." It is not necessary however that the road should be a cobblestone pavement. Here is an opportunity to make it a beautiful asphalt pavement over which the students glide in observation auto cars.

Third question: How should recitations, written reviews and examinations be conducted? It is to be understood by the class that on its assembly for the next period for instruction from its teacher, that questions in review of the previous lesson will be asked. A question asked by the teacher is addressed to the entire class; those able to answer will indicate by the uplifted hand or by rising. From this number one is called upon to answer. Usually 10 or a dozen questions will review the entire lesson and but a few minutes are required. Written reviews are desirable. After the pupils have written the answers to the questions asked they exchange papers and look over the work of one another. The results may be marked by them, the papers are then returned to their respective owners, when the teacher will give the correct answers, corrections in the markings may be made if necessary. This is of real educational value. Formal examinations should take place as infrequently as possible. They are only of value to determine the class standing of the student. They are of no educational value.

Fourth question: What amount of time should be devoted to laboratory work and what should be the nature of it? In the teaching of physics in the secondary schools it is very desirable that an entire year be devoted to the subject. If for example the entire time amounts to 160 hours it would be fair to divide it equally between class teaching and laboratory work. The class teaching is of primary importance. If the time has to be lessened, let it be taken from the laboratory portion.

As regards the nature of the work, the students are to repeat the classroom experiments as far as practicable. Many of these will be qualitative rather than quantitative. The apparatus should be permanently arranged in the laboratory with accompanying directions. Inasmuch as the apparatus can not be duplicated to any great extent the students may take turns in performing the experiments at convenient periods. The special laboratory experiments should, as a rule, be for the purpose of verifying laws or principles. So called research work does not belong in the laboratory of the secondary school. The apparatus should be of a substantial nature, readily manipulated and requiring a minimum of time in its prearrangement. It is impracticable to have a large number of students performing the same experiment at the same time, for this requires a duplication of apparatus and room capacity beyond what can be usually afforded. When the attempt is made the apparatus is apt to be cheap and unsatisfactory and the experiments trivial and uninteresting in character. The students should have proper supervision. Ten or twelve students to one supervisor constitute a sufficient number.

Fifth question: Of what use are practical problems and to what extent are they to be employed? They are of use in making clear the real meaning of formulas. Often times a formula stands for several rules. There should be problems enough to illustrate the application of them all. Practical problems in considerable number should be combined with laboratory work. They should be simple and all mathematical demonstrations of a complicated nature are to be avoided.

Sixth question: What has been the occasion of the decline in interest of the study of physics? What can be done for the revival of the interest? We now come to the consideration of a very serious condition. That there has been a decline in interest is generally conceded by those who have been teaching the subject for the past 20 or 25 years. How can this be accounted for? Within the past 20 years decided changes have taken place in the teaching of physics. The emphasis placed upon laboratory work has been one important cause. The college entrance requirements and the report of the committee of 10 have been also controlling influences. About this time the change in the name from natural philosophy to physics occurred. In many cases the classroom work has been made subservient to the laboratory. The hearing of recitations has taken the place of class instruction. This has been the maxim of many instructors: "That only is knowledge which the pupil has reached as the result of experiment."

In many cases abstract mathematical treatment has taken the place of experimental methods. Can we in the above statements trace any relation of cause and effect? It may seem a matter of little importance, that a name is of any significance in this connection. It is my belief that the change in name from natural philosophy to physics was unfortunate and without really any good reason. To most young people the term physics has unpleasant associations. The term is far more comprehensive than in its present limited signification. Natural philosophy, on the other hand, has its pleasing associations. A philosopher is a lover of wisdom. A natural philosopher is one who loves to know about the phenomena of nature. Any boy or girl would far rather be called a philosopher than a physicist. If possible let us have a restoration of the old name. The idea that high school pupils are to be placed in the laboratory to rediscover the laws of nature is to be given up. When we remember that the discovery of these laws has required many centuries of time it is unreasonable to suppose the students can accomplish the work in a few hours. Again to discover a new law implies inventive ability. This is a faculty possessed by few. The high school pupils are close observers and imitators. When they know definitely what they are to accomplish and just how it is to be done their work becomes interesting and delightful. If the students had unlimited time to spend in the laboratory it might be otherwise.

> Could a man be secure
> That his days would endure
> As of old for a thousand long years,
> What things might he know:
> What deeds might he do!
> And all without hurry or care.

Again many laboratory experiments are of a trivial nature and lead to no definite end in the way of scientific value. Let the experiments be of such a nature that there will be "something doing." High school boys and girls are a good deal like *Helen's Babies.* "They want to see the wheels go round." Let us have more qualitative experiments and others tending to reveal the real practical nature of the subject of physics. College entrance requirements should not be a governing influence in the teaching of physics. Comparatively few pupils enter college. Those who do may have special work assigned them. The subject is to be pursued for its intrinsic worth; when this is the case the students will soon realize that the knowledge thus gained is of real practical benefit, enabling them to understand the phenomena of everyday occurrences. They are acquiring a liberal education, that which tends to liberate them from the bondage of ignorance. Abstract mathematical reasonings as a rule are to be avoided. The investigation of the laws of nature should proceed from the experimental standpoint, not the mathematical. The mathematics of physics should be made as simple as possible. Biographical and historical references are always interesting. Essays may be written descriptive of the lives of scientists and scientific events, which when read by the writers will add much real interest.

Dr Forbes presented a number of pieces of apparatus of original design. In his demonstrations he was able to exemplify many of his suggestions in regard to the teaching of physics.

SOME PRACTICAL PHYSICS APPARATUS

WILLIAM TIMBIE, PRATT INSTITUTE, BROOKLYN

There is no course of study that comes nearer the student's daily life than that of physics, excepting possibly chemistry. The great argument for including physics in the curriculum of the high school is this vital connection with the student's life. Now when this connection between the classroom instruction and practical everyday life has been removed, or lost sight of, in the struggle for uniformity, or for any other reason, then the life, the whole vital part of our science has been taken away from us, and what remains to us is dead. And the teacher who allows his better judgment to be overcome, who gives up trying to get his science its rights, his students their rights, and himself his rights, soon begins to be attacked by a dry rot and he becomes a " dead one " too.

It is for this vital connection between physics and the everyday happenings in the lives of our students, that I want to make an appeal to you. I want you to forget for a moment (and I wish you would forever) the high and mighty board of examiners, the Regents requirements, with all the minimum experiments to be performed and minimum number of pages of some " approved " textbook to be learned. Then, and then only, can we get at the larger questions of why we teach the students physics at all, and why we use the laboratory method. Then, when we meet on this ground, we can discuss to some advantage the best things to teach in the time allowed us, and we can present apparatus before a convention like this and have a rational discussion of its merits and demerits.

The men in our profession whom we look up to as the exponents of right teaching methods, are almost unanimous in their condemnation of this cut and dried system of physics teaching, which has been in vogue for 20 years. You will find the wide-awake physics teacher of today looking about, continually, for every possible means of bringing his subject back to life, back to the important place it should hold in every high school and college, and more than all that, back to the interest and respect it should excite on the part of every student. All this can be done; has been done. It is a matter of history that wherever the physics course is allowed to develop naturally, it soon becomes in the students' eyes, and, you may be sure, in the teacher's eyes, the one course of absorbing interest. Such a teacher isn't interested in new-fangled, highly specialized pieces of apparatus. He's on the lookout for apparatus and methods which will increase and make the most of the points of contact between his instruction and the students' experience.

That's why I'm here; to get pointers from you. And too, I hoped that, in our experience at Pratt, we might have developed things that will help some of you. I fully appreciate that our problem is different from most of yours. The problems that a physics teacher must solve are different in different localities, and even different among the several schools of the same locality. Yes, the best physics teacher will consider each student a separate problem, and as far as possible, lay out a course, especially in the laboratory, which will best meet that particular student's special needs.

Thus, though our problems may differ in minor details, they all have this principle in common. We should all be trying to arrange our course so that it touches the student's life in as many points as possible. This is what should be understood by the term "practical physics."

We came to believe, years ago, that such a practical course in physics was the only course which had a right to the name of "physics." The trivial, tiresome stuff in the common textbooks which has so long masqueraded under the name of physics, and the barnlike room, empty, save for a few tables, or some "dinky" wobbling piece of apparatus, which has so long passed muster as a physics laboratory; these, have already done their deadly work in killing the natural impulses of every live up-to-date boy. He wants to know how a dynamo "dynes" and why a motor "motes." And what sort of stuff do we hand out to him? Think of a physics course of which one third of the laboratory work in mechanics consisted of finding the specific gravity of different substances and about the same proportion of the work on electricity being on static electricity. One might as well teach the alphabet to high school students and call it a course in English literature.

And so at Pratt, we have tried to meet the needs of our pupils by keeping in close touch with their past experiences, their daily lives, their aims and their ambitions. With these ever in mind, we have, for 9 or 10 years, been developing a course in physics which, on the one hand, will best aid them to realize their ambitions, and on the other, will enable them to bring to bear on their studies the knowledge gained by their past experiences and their daily life.

The problem falls naturally into two parts: What is it best to teach? What is the best way of teaching it?

As to the first, we have learned it is best to teach the pupils a *few* broad, but definite principles (not formulas) and their ***many*** practical applications to modern industrial life. Concerning the second, we have learned that that method is best which will best keep the students' interest and respect. The natural interest in these things can be kept, and new interest and respect can be gained by placing interesting and respectable apparatus into the students' hands.

To illustrate: Every individual in practical life, especially if he has been, or is to be, engaged in any kind of industrial life, would profit by some definite ideas regarding the common effects of forces. From the three or four laboratory exercises usually given to this subject in college preparatory courses, performed on trivial apparatus, and with nothing to suggest the practical applications of the principles involved, the pupil gains but little real information. He does not appreciate that the slight cord, or the suspended rod, or the delicate scale pan and weights, may be replaced by the cables and steel girders and massive loads of real structures; and the exercises appear to him most abstract, if not altogether meaningless.

Therefore, for the pupils in the high schools, many of whom may never have an opportunity to study applied sciences in a higher institution of learning, we have provided, instead, a laboratory filled with simple belted and geared machines, with pulleys and shafting, with jackscrews, hoisting tackle and working models of actual structures, such as cranes, derricks, shear legs, arches, roof, bridge trusses, etc. These are large enough to inspire the respect of the boys, and strong enough to permit their being loaded with weights of respectable magnitude. Repeated exercises performed on such apparatus, with loads arranged in a great variety of ways and supplemented, of course, by classroom discussions and plenty of problems, furnish concrete conceptions of both the basic laws and their practical applications which are definite and lasting, and also useful.

I had a young man come to me the other day with the stresses in the different members of the elevated structure all worked out. I asked him where he got the proper angles, loads etc. He had measured the angles by climbing up the supporting pillars and had spent a Saturday in hunting up a designing engineer of the railway company who would give him the weight of trains, etc. I think this young man is interested in physics, and I believe we have taught him the parallelogram law at least, in such a way that he respects it and appreciates its value.

Again, in college entrance physics, the mechanics of moving bodies, and the relation of such motion to the forces which cause it, is almost entirely omitted in the laboratory work, and is much curtailed in the textbook instruction. When one considers the extent to which the industries are dependent upon machinery in motion, argument is not needed to show that there is here a most important field that should be thoroughly covered in the science course of the ordinary high school. The driving force of shafting and gears, belt tensions, changes of speed, the influence of fly wheels and of unbalanced moving parts, brake forces for stopping machinery, the time required for getting it under way again and the forces involved due to the inertia of matter, are ideas which should be made very clear and definite; and the principles underlying them should be thoroughly understood.

Ideas of work, energy, power, and efficiency are equally important. The experiment for illustrating efficiency, the usual one in college preparatory courses, is a system of pulleys, small, accurately balanced and operated by a thin cord or thread lifting a few ounces. This has always impressed me as being most ridiculous. Let such an experiment be performed by all means, but with a commercial block and tackle and rope not less than ½ inch thick, and lifting 100 to 200 pounds, and let the sheaves be the usual ones used in any shop and purchased in any hardware store. These are the commercial conditions, and the conclusions drawn from an experiment thus performed would have some interest and value.

The laboratory of the ordinary high school, in my opinion, should contain in place of the regular school apparatus, a proper supply of common commercial machines which would give an opportunity for plenty of tests of efficiency, friction, input and output, on gears, sprockets, and belt-driven machines, fly wheels, bearings etc.

Similar useful exercises may be suggested for heat and electricity; apparatus may be readily arranged in which steam in quantity may be used to illustrate such ideas as the relation of its pressure to its temperature, its energy, its condensation, its power of doing work under expansion, etc., and these things may be shown just as simply as with the trivial exercises that are usual in the school laboratory for illustrating the laws of heat. I am to demonstrate one such piece for determining Joule's equivalent and for using it.

In the subject of electricity, the instruction given in most high schools, is only that included in the usual college preparatory courses in physics as outlined by some textbook. It is illustrated either by the use of apparatus that is small and not practical, or else by highly specialized instruments for purely theoretical measurements and deals for the most part with either frictional electrictiy or with the current from battery cells. Most of the exercises in the course are given unchanged just as they were adopted for the original report of the "Committee of Ten" some 20 years ago, and are not at all representative of modern practice or the uses to which electrical power is now adapted.

All the electrical theory that is necessary for a general understanding of the subject or that is suitable for a secondary school, may be equally well illustrated by the use of commercial ammeters, voltmeters, and wattmeters, and with current from a generator. In this way, the instruction may be given a highly practical value. Model lighting circuits should be arranged in the laboratory, upon which tests may be made of the distribution and utilization of electrical power, the current needed for different circuits, electrical resistances, the power required to operate different kinds of lamps, etc. Small motors of, perhaps, one half horsepower or one horsepower, should be installed from which the structural details of motors and generators, their connections, their operation and control, and the interrelation of mechanical and electrical power may be learned. In these days of electric lighting, electric traction, and electric machinery of every variety, these are matters upon which every intelligent person should be informed.

These suggestions are a few of the things that we have worked into suitable exercises for a course in physics. They are far from complete, but presumably enough have been given to make clear the points which I wish to emphasize. Work and instruction of this character is successfully given in other schools than Pratt, to pupils of ordinary high school attainment. It is simpler of comprehension than much of the work required by the examiners, and it offers in addition to its everyday utility, a more efficient means of furnishing training and mental discipline.

There should not be the slightest attempt to encroach upon the field of the college engineering in any of this instruction; but such principles, underlying the construction of this apparatus and machinery as are necessary to a proper and intelligent care and efficient use of the same, are entirely within the scope of the high school, and should by all means be included in its curriculum.

1 Determination of the value of Joule's equivalent by a simple form of apparatus

The apparatus shown in figure 1 was devised wholly from commercial parts, first to determine Joule's equivalent, second to obtain a maximum value for the fraction of the energy input of an ordinary incandescent lamp which is turned into light. It consists of a 32 candlepower bulb in a micanite weatherproof socket, into which is screwed a short piece of brass pipe joined at the upper end to a wooden head. This head carries a pair of Fahnestock binding posts for the terminals of the lamp. The joints are sealed by beeswax above and below.

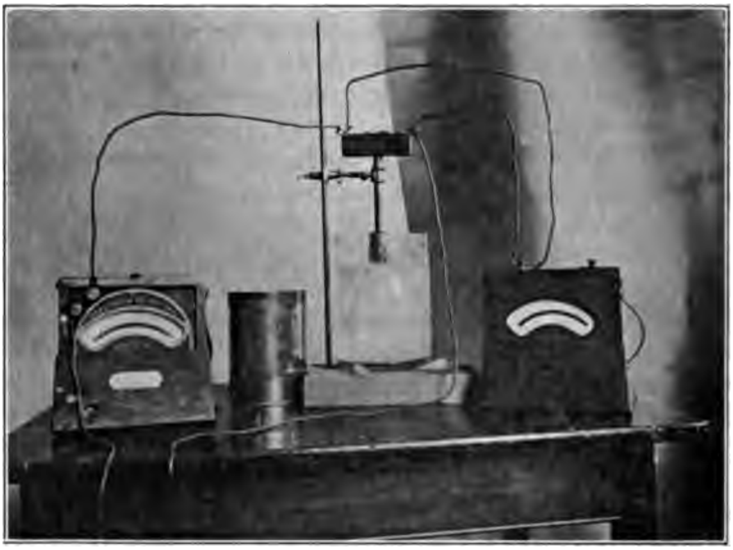


Fig. 1 Apparatus to determine Joule's equivalent

Used in a metal calorimeter with a cover, the apparatus converts the entire input directly into heat; while if the bulb is placed in a thin beaker of very clean water the light given off is apparently as bright as though the lamp were burning in air, but the heat developed is 10 to 13 per cent less. This gives a maximum value to the absolute efficiency of the lamp in converting electric energy into light.

Some simple experiments involving the Wheatstone bridge principle of resistance measurements were shown. These consisted of the Varley and Murray " loop " methods of locating a " fault " in a telephone or a telegraph cable. The merit of these experiments lies in the fact that they give practice in resistance measurements applied in an interesting and commercial manner, with the use of simple inexpensive apparatus. Every student is naturally curious to know how it is possible to sit in an office and send a " repair " man to within a few feet of a " fault " in a telephone line which may be miles long. Use is made of this curiosity to drive home the fundamental principles of a Wheatstone bridge.

Stereopticon pictures were then shown illustrating how models of cranes and bridges had been made, and simply made, for laboratory practice in mechanics.

Three of these are given below.

2 Pair of shears

Figure 2 shows a pair of shears erected at Sparrows Point, Md., for the Maryland Steel Company. The two legs are hollow steel tubes 116 feet long and inclined 35 feet out of the vertical. They are operated by hydraulic machinery and designed to lift 200 tons.

This mechanism affords an interesting and easy classroom problem for the application of the principle of the equilibrium of concurrent forces. In addition, a model has been made and set up in the laboratory. The students may compute the stresses in all the members for different " set ups " and then check their computations by testing the stresses in the model with spring balances. Figure 3 is a photograph of such a model pair of shears set up in the physics laboratories at Pratt Institute.

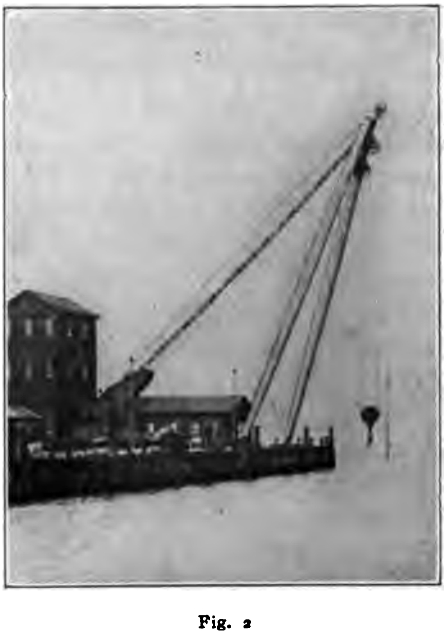


Fig. 2

The legs are about 4 feet long of 1½ inch oak. The "feet" are tapered and set in holes in the board MN which is screwed fast to the table. Several quick adjustments of the "spread" are thus possible. The legs are joined at A by a hinge, the pin of which passes through a clevis. By fastening a balance to the clevis and pulling up, along the line of a leg, until the foot just clears the support, the thrust at foot of the leg may be determined. The tie is of braided wire and, by an easy adjustment of its length, the legs can be inclined at any angle to the vertical. A spring balance placed in the tie registers the tension in that member. In this form, a pair of shears makes an easy and very practical problem which can not only be solved, but the computation can be checked by actual tests to within a few per cent of variation. The fact that it is a good sized working model of a commercial machine, adds a large element of interest to the student's work.

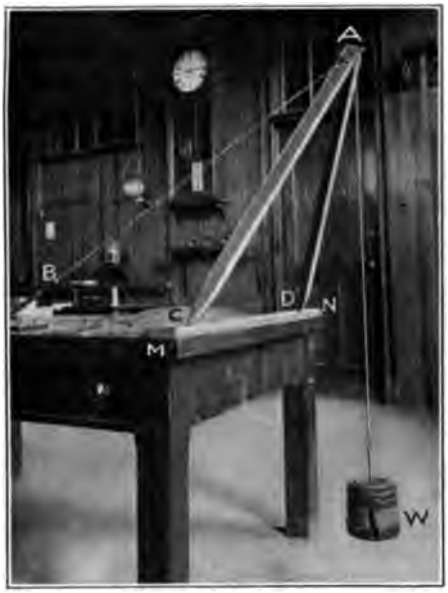
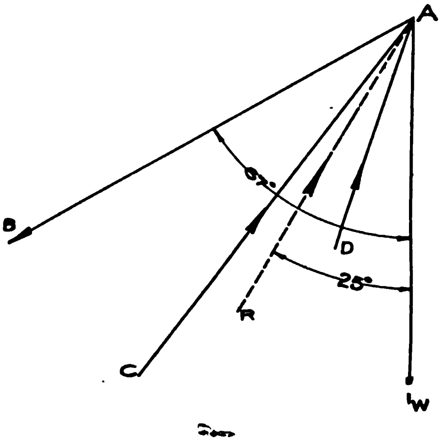


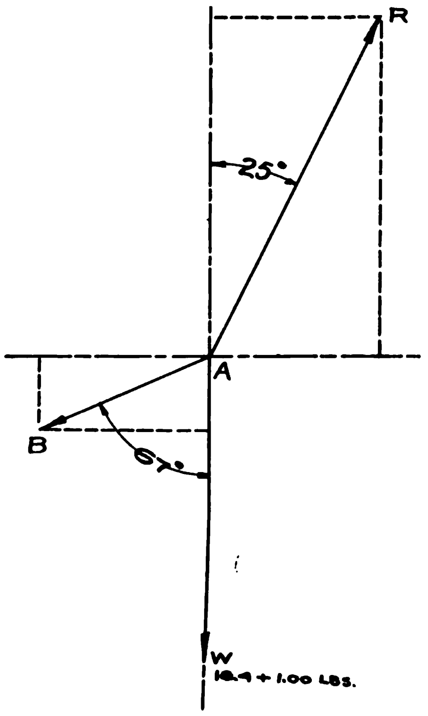
Fig. 3

The method of solution usually followed in our laboratories is as follows: About a 20 pound load is hung at W. The legs together weigh 2 pounds, and as one half of this may be considered as acting at A and the other half at the feet, 1 pound is added to the weight W, in all computations.

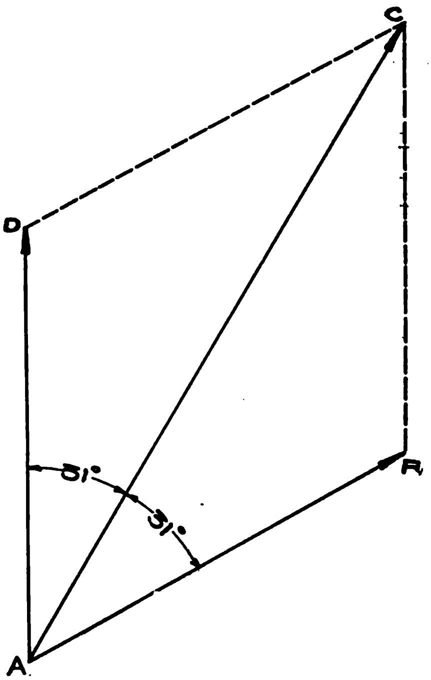
The thrusts in the legs may be imagined to be taken up by a single member in the plane of AB and AW running from R to A [*see* Force diagram 1]. We now have a simple case of equilibrium produced by three forces meeting at a common point. The stresses in tie AB and imaginary leg AR, are now found graphically or by trigonometry. Using the same methods, the force AR is then resolved into its two components along the legs, AC and AD. By adding to these values .7 pound, (the effect of the remaining



Force diagram 1



Force diagram 2



Force diagram 3

weight of the leg), the thrust at the foot is found. These results are then compared with the test readings, taken as described.

3 The chain hoist

Among the different classes of machines the nonreversible type presents interesting problems in efficiency, displacement ratio, mechanical advantage, effect of load on friction, etc. By nonreversible type is meant a machine which will not be run backward by the load when the driving effort is removed. To this class usually belong the screw, worm, differential pulley, etc.

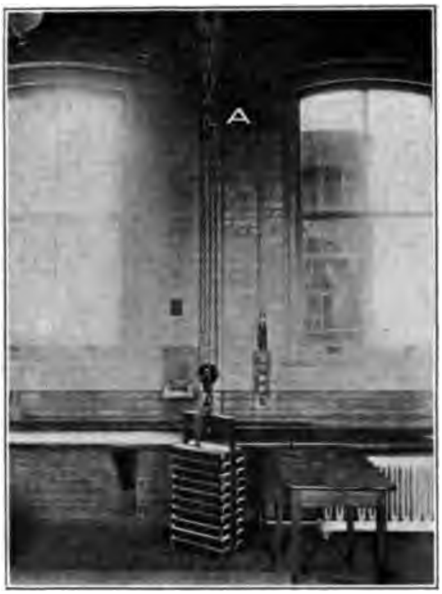


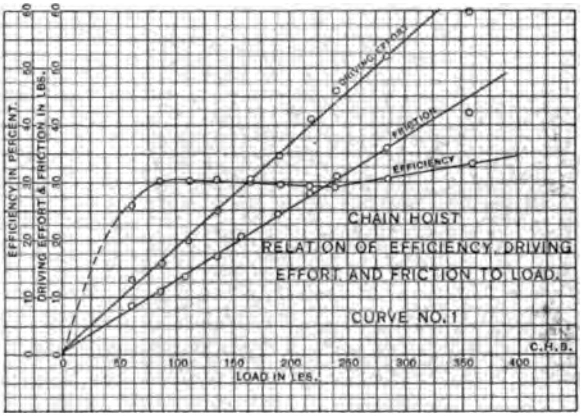
Fig. 4

Figure 4 shows a quarter ton chain hoist which has been installed in the physics laboratories. It is a Weston differential pulley type, made by Yale and Towne, and is the regular stock hoist of quarter ton capacity and 8 feet lift. No effort has been made to reduce the friction or otherwise improve the apparatus. The test is meant to be strictly of a commercial character and under actual working conditions.

This type of hoist was chosen for the beginner in preference to the worm and wheel hoist because the differential block (A) is open and allows the student to get at the mechanism (two pulleys), and so obtain measurements and observe its action. This block is fastened to an I beam. The load consists of an iron cradle and nine 50-pound weights which may be added one at a time in order to test the machine under different loads from 50 to 550 pounds.

The procedure is as follows: The diameters of the differential pulleys are first measured and the displacement ratio computed from the formula $\frac{2R}{R-r}$ where R is the radius of large pulley and r the radius of the smaller one. This is then checked by measuring the length of chain running over large pulley, which has to be displaced in order to raise the load 1 foot.

The effort required to raise a given load is measured by pulling on a spring balance attached to the chain. As the machine will not run backward, a negative effort, i. e. an effort on the other side of same pulley, must be applied to lower the load. The amount of negative effort is determined in the same way as the effort required to raise the load Half the algebraic difference of these two quantities is approximately the value of the friction at that load. The output is computed by assuming load to lifted 1 foot, thus: output=load × 1 foot-pounds. The input then equals the product of the displacement ratio, by the effort to raise the load. By dividing output by input, the efficiency is found at the given load. This is repeated for loads increasing by 50-pound steps until a load of about 550 pounds is reached. Interesting curves are then plotted showing relation between load and effort, load and friction, and load and efficiency.



4 The chain drive

Efficiency of transmission

The chain drive has probably reached its maximum efficiency in the bicycle. In order to obtain minimum friction the teeth are cut very accurately and the chains are made with great care. Here, then, is one of the best examples of a common method of power transmission which is very easy to instal in a laboratory, and which offers an interesting problem in maximum commercial efficiency of a certain type of mechanical transmission.

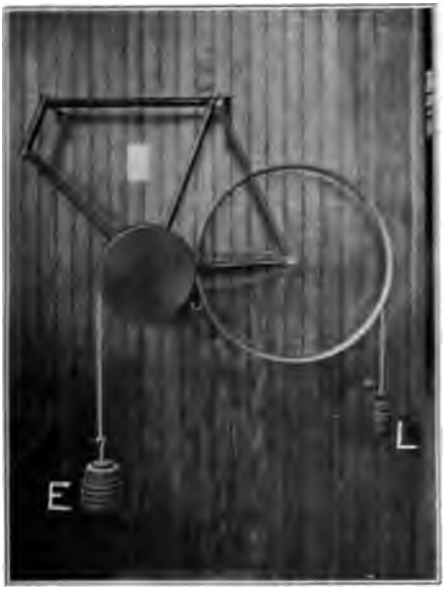


Fig. 5

Figure 5 is a photograph of such a mechanism installed in the Pratt laboratories.

The pedals were removed and a wooden pulley having a radius equal to the length of the crank was attached to one crank. A pound applied to the rim of this pulley thus produces the same torque as an equal force formerly did, when applied to the pedal. A resisting torque is applied to the rear wheel by a weight on the cord running on the rim, from which the tire has been removed. If desired, the machine may now be driven by the force on the rear wheel. This will raise a greater weight on the pulley, thus gaining a large " mechanical advantage." Or it may be driven in the usual way as a " speed " machine with the force on the pulley used as the driving effort. The latter is usually our practice.

A two-ounce load is hung from the rear wheel and then enough weight put on the pulley to just raise this at a uniform speed. Then weights are removed from E until the load (L) lowers at the same uniform rate. Half the difference between these values (effort to raise and effort to lower the load) represents the friction of the machine at this load. The driving effort for a frictionless machine can be found by taking half their sum. The input, output and efficiency are computed as in the experiment with the chain hoist, and curves are plotted to show the relation of efficiency and driving effort to load raised. Also on the same sheet the driving efforts for a frictionless machine are plotted against the loads. The increase of friction with added loads is brought out by the divergence of the two "effort" curves. The displacement ratio is computed by measuring the diameters of the pulley and wheel, and counting the number of teeth on each sprocket. The computed value is then tested by actual measurements of the distances moved over simulneously by effort and load.

A SIMPLE HYDROGEN SULPHID GENERATOR

JENNIE P. HANNA, EAST HIGH SCHOOL, ROCHESTER

The idea of this little hydrogen sulphid generator is not original, as I found the suggestion in the March, 1908 number of *School Science*.

This generator consists of ignition tube (although test tube can be used) through the bottom of which I blew a small hole. I melted the end of a small piece of tubing, about 2 cm in diameter, whose coefficient of expansion is about the same as ignition tube. Blew a small ball at end and broke it so as to leave a slight flare. Then drew tubing through hole and melted the flared end to ignition tube. Immediately covered end with carbon by holding in luminous flame, thus giving it a chance to cool slowly.

The generator is charged by dropping two or three small pieces of $Fe S$ into tube, so that they lodge in annular space, add a little dilute acid and close with finger on stopper.

If you wish to collect the gas to study its properties, put generator into bottle and cover, using lead compound to determine when bottle is full.

After use, the generator is stopped by filling tube with water.

This tube is efficient in precipitating the sulphids from their salts, as it not only generates the gas where needed but can be used as stirring rod. The pressure of the gas is sufficient to keep precipitate from working up into small tube.

Miss Hanna also exhibited a wooden model of a calcium carbide furnace, that was made by one of her students.

DEMONSTRATION OF DYNAMO AND MOTOR

BRYAN O. BURGIN, ALBANY HIGH SCHOOL

I Apparatus. Dynamo-motor, sensitive lecture table galvanometer, large bar magnet, eight to ten volt battery, connecting wires.

The dynamo-motor. A bipolar field is built of large upright cores separately wound for each pole, all windings and connections being exposed to view so that circuit of exciting current may be easily traced and polarity of field determined. The diameter of space between curved pole tips is about 4½ inches.

The armature consists of a single rectangular coil of 125 turns of no. 24 magnet wire wound on a light brass frame about 4 inches in diameter, so made that it may be easily and quickly put on or taken off of a wooden shaft on which it may be rotated in the field. The shaft on which may be fastened the armature coil, collecting rings or commutator is about 10 inches long and may be instantly placed in bearings or removed therefrom. The shaft bearings consist of two iron uprights about 8 inches high from base of machine.

Collecting rings, 2½ inches in diameter, are so built together that they may be easily put on and clamped to the shaft and the two terminals of the armature coil readily connected. To distinguish conveniently between the two rings, one is colored red and the other blue, and the similarly colored terminals of the armature coil may be connected to the rings respectively. A two segment commutator, one segment red, the other blue, 2½ inches in diameter, is also so made that it may be readily clamped on the shaft in place of the collecting rings, and the terminals of the armature coil quickly connected thereto.

Two thin strips of spring copper about 5 inches long and ½ inch wide constitute the brushes which may be instantly adjusted under binding posts to bear on the collecting rings or under another set of binding posts to bear on the commutator. A small crank which may be quickly attached to rear end of armature shaft, for convenience in rotating same, completes the machine.

II Demonstration. *A — The dynamo*

(*a*) Before presenting to a class, the subject of the dynamo, the following principles should be thoroughly fixed in the minds of the pupils: (1) Induced electro-motive forces and the resulting currents are always produced in a closed conductor, as a coil, by a variation in the number of lines of force passing through the coil. (2) An induced current is said to be direct when it flows clockwise in the coil, and indirect when it flows counterclockwise. (3) If the observer imagines himself looking in the direction in which the magnetic lines of force pass out of north pole of the inducing magnet or coil, then an increase in the number of lines passing through the coil induces an indirect current and a decrease in the number of lines induces a direct current.

(*b*) Determine the polarity-deflection of the galvanometer by the use of a copper-zinc water battery.

(*c*) Substitute armature coil for battery, connecting red terminal of coil to galvanometer wire which was connected with copper and blue terminal in place of zinc.

(*d*) Using bar magnet, verify statements in (*a*).

(*e*) Connect field magnets in series with 8 to 10 volt battery; apply right-hand polarity rule and verify same by means of magnetic needle.

(*f*) Using field magnets, verify statements in (*a*).

(*g*) Place armature coil on shaft, put shaft in bearings, rotate and note deflection of galvanometer needle. Also note twisting of wires due to rotation of armature.

(*h*) Show how twisting of wires may be avoided. Put on collecting rings — connecting colored armature terminals with respective rings — and adjust brushes, galvanometer wires and crank. Rotate armature and note deflections of needle indicating alternating current.

(*i*) Emphasize the fact that the current changes direction twice during each revolution, namely at times when the greatest number of lines of force are passing through the armature coil.

(*j*) Show how current might be taken from armature coil in same direction through external circuit by rapidly exchanging places of brushes at every alternation. This may actually be done by placing both collecting rings on the same wheel, letting one ring be represented by half the circumference and the other ring by the other half. Show and explain construction of the commutator.

(*k*) Remove collecting rings, put on commutator, connect with terminals of armature coil and adjust brushes. Clamp commutator on shaft so that segments change from one brush to the other at the time current changes direction in armature coil. Rotate armature and note constant deflection of galvanometer needle indicating direct current. Reverse rotation and note deflection of needle showing opposite direction of current.

(*l*) Call attention to the fact that the field of an alternator must be excited by a direct current from some outside source (unless a portion of its own current is rectified as is sometimes done), while a direct current dynamo may excite its own field. Show also how the armature core may be used and its effect on the number of lines of force passing through the coil.

B — The motor

(*a*) In presenting the subject of the motor it is essential that the pupils understand thoroughly the nature of the magnetic field which surrounds a current-bearing conductor. They should know the following rule: Knowing the direction of the current, grasp the conductor with the right hand so that the thumb points in the direction of the current, then the fingers will indicate the positive direction of the lines of force around the conductor.

(*b*) Connect field magnets in series with battery and determine polarity.

(*c*) Break circuit and making a loop of one of the connecting wires place it between the pole pieces of the field magnet. By the application of the rule stated in (*a*) and the laws of magnets, determine what should be the motion of the wire when current flows.

(*d*) Make circuit and verify conclusion drawn in (*c*). Reverse loop of wire and note result when current is again made to flow.

(*e*) Place armature coil and commutator on shaft, connect and hang shaft in bearings. Adjust brushes, trace out circuit and determine how armature coil should revolve when current flows.

(*f*) Make circuit and verify conclusion drawn in (*e*).

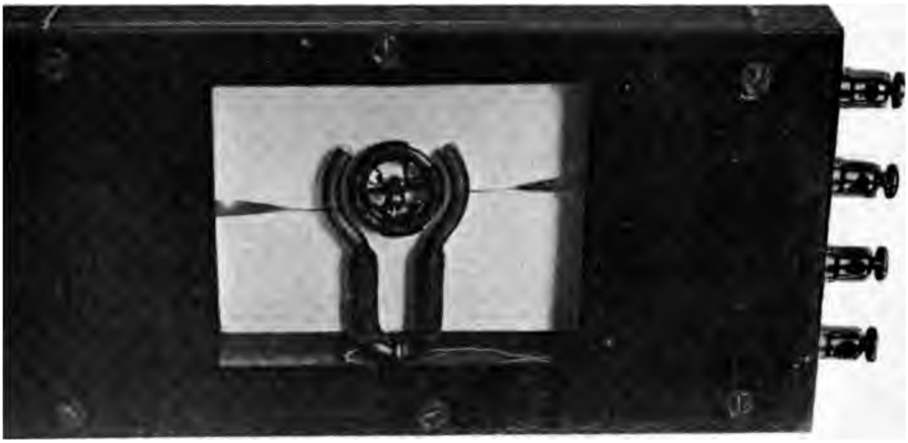
(*g*) Show how reversing the current in a series motor does not and can not reverse the motion of armature since the polarity of the field is reversed as well as the current in the armature.

(*h*) Point out the fact, as in the dynamo, that a laminated iron core increases the efficiency of the motor by impelling a greater number of lines of force to pass through the coil.

BRIEF DEMONSTRATIONS

CHARLES L. HARRINGTON, BROOKLYN INSTITUTE OF ARTS AND SCIENCES

Small model of ring armature motor to be used for projection by a lantern



This motor possesses all the necessary working parts. The binding posts, a and b, should be connected to the poles of two dry cells in series, while c and d are connected to the poles of two other dry cells in series. By using two double-throw switches (one for each pair of cells) it may be shown:

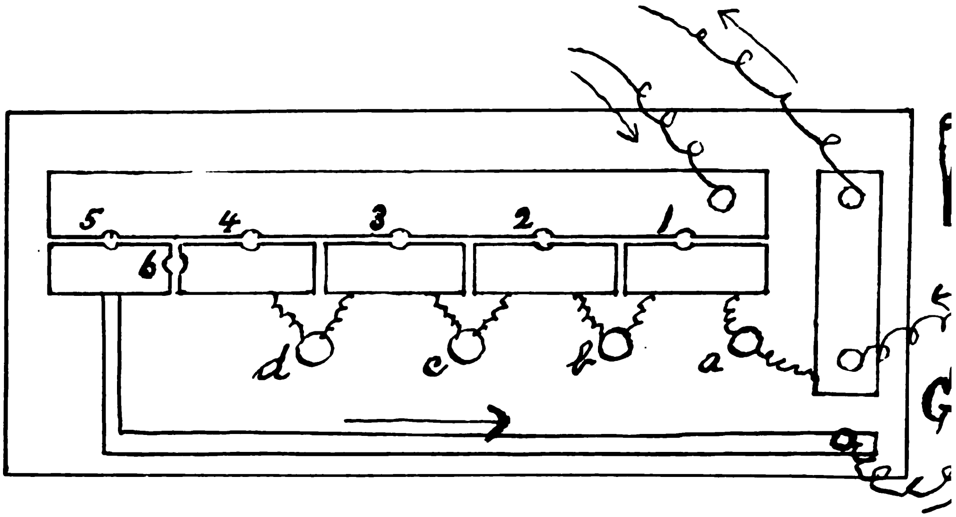
1st That the armature turns rapidly when both currents are working.

2d That when both currents are reversed the direction of armature rotation is not changed.

3d That when only one of the currents is reversed the direction of armature rotation is changed.

Displace the cells, c and d, by a galvanometer. Then by attaching a pulley to the axle of the armature, the armature may be made to turn in a magnetic field and the galvanometer will show a current. Thus muscular energy may be changed to electric energy.

Modification of the Ayrton rheostat



Resistances

a = .28 ohms
b = 2.52 ohms
c = 25.20 ohms
d = 28.00 ohms
g = 224.00 ohms

Total = 280.00 ohms

Decimal parts of total resistance

a = .28 = .001
a + b = 2.80 = .01
a + b + c = 28.00 = .1
a + b + c + d = 56. = .2

PLAIN CROSS SECTION DRAWINGS ON CARDBOARD FOR SCHOOL USE

S. B. EVERTS, ADAMS HIGH SCHOOL

In physics and chemistry as in other subjects there are certain fundamental principles to be fixed in the minds of our pupils if any real understanding of either subject is to be obtained. It is the purpose of this paper to discuss briefly the importance of drawings in inculcating these scientific principles, and to urge that sectional drawings be more extensively used in textbooks and by teachers and students. While the discussion will be of interest to all science teachers, it is my hope that it will be of special assistance to those who have but recently entered upon the work of teaching.

That more attention should be given the matter of drawings on the part of our teachers and textbook writers needs little argument. Our textbooks and laboratory manuals are in general much better illustrated today than were those in use even 10 years ago. The cuts employed to represent various pieces of apparatus are much clearer and greater pains is taken to illustrate the actual commercial form of the apparatus under consideration. In some of the more recent texts we may find excellent examples of color work, especially in connection with the subject of light. In the matter of sectional drawings, however, most texts are still deficient. The drawings shown in many books even for simple pieces like the ordinary force pump, for example, closely resemble Patent Office drawings, while the drawings to illustrate the arc lamp with automatic feed confuse and discourage the best students at first sight. Sometimes a cut is used which shows a picture of the cross section, and often a cut is given and no sectional drawing whatever is offered to aid the student. It is safe to assert that not one pupil in ten attempts to master by his own efforts such drawings as are usually placed before him. He gives up the attempt in disgust, if he makes one at all, and relies upon his instructor to show him "how it works." Textbooks should contain in close proximity to each description not only a good cut but also a clear, simple, sectional drawing of the apparatus, with references in the text to the drawing as well as to the cut presented. These drawings should be so made that the significant facts of the apparatus will be firmly impressed upon the student's mind when he has completed the study of the text relating to the matter.

But teachers are at fault in this matter as well as textbooks. A pupil is often directed to make a drawing of some piece of apparatus with which he has been working, the task being assigned without any preliminary assistance or instruction as to the essential parts to be drawn or the conventional methods of representing these parts. The pupil confronted by this problem usually does one of two things: either he openly or surreptitiously finds a drawing of some sort in his textbook or laboratory manual and then proceeds to copy it carefully into his notes, or else he produces by his own efforts a drawing out of proportion, with emphasis placed upon the wrong features, and with many minor but necessary details omitted. In either case it is safe to assume that he goes away and at once forgets what manner of thing it was that he drew. Later upon written test his instructor is surprised and pained to find that the student either fails entirely when called upon to illustrate his description of the apparatus in question or else his drawing and description do not agree. Examinations for State certificates prove that this deficiency is widespread and that inaccurate and incomplete drawings are the rule and not the exception. Every physics teacher will testify that pupils are prone to confuse the lift pump and the force pump, to omit valves, to place levers so that the motion produced will be incorrect, to form ropes and pulleys into impossible combinations, to produce wild tangles of wire in electrical apparatus, and to fail utterly to trace the path of a ray of light through a lens. In chemistry the drawings presented will not show the actual arrangement or will fail to show stopcocks, rubber connections, corks etc., without which the apparatus would be useless. This condition points to vague ideas and a weak grasp upon essential principles, and demands vigorous treatment upon the part of our science teachers if improvement is to be secured.

It is almost axiomatic to affirm that no student can fully understand the apparatus he is studying unless he can make a simple but accurate drawing to illustrate its construction and operation. Graphic illustrations are helpful in any subject but nowhere are they of more value than in the sciences. Pupils should be taught to form correct visual images of the cross section of the apparatus they are using. Without doubt one of the chief reasons why principles of physics which relate to common things such as the ordinary lift pump are so slowly apprehended is that plain drawings are not presented for study nor is aid given the student so that he can make such drawings. Students may use a simple air pump or gas generator for months and be unable to explain its de of operation or make an intelligible drawing of it. Hazy and erroneous ideas can often be located and corrected in no other way so well as by requiring the student to make a drawing of the apparatus. If the student secures by daily practice the ability to draw accurately and rapidly the apparatus he is using, he will receive much valuable training in designing new combinations to secure some desired end. Finally, the consciousness on the part of the pupil that he can draw some troublesome arrangement or complicated apparatus greatly increases his confidence in his ability to describe it lucidly and accurately when necessary.

The first essential of good laboratory drawings is rigorous simplicity. Only parts essential to a clear understanding of the principle under consideration should be shown. In accordance with this idea, pupils should be taught to omit detailed drawings of levers and other devices to produce motion, the direction of motion being shown by arrows. Dynamos and batteries should be represented by conventional signs or omitted altogether. Any detail of structure shown in the commercial model which is unnecessary and which may serve to distract the pupil's attention should be omitted. The constant aim should be to strip everything of that which is incidental or unnecessary and concentrate the attention upon the principle in hand. Students should not be allowed to make excellent drawings of ring stands or burette clamps and then fail to show clearly the apparatus of which these are merely the supports.

A second essential is that drawings be cross sections of the apparatus used. Pupils should be directed to imagine that a vertical plane is passed through the middle of the apparatus and then the sheet of paper is put in the place of this plane. Lines are then traced where the paper would touch the intersected apparatus. The teacher must explain this principle carefully and enforce it by much practice. Special directions will be needed in both physics and chemistry. For example, students must be shown that the bottoms of bottles, flasks, cans etc., must be represented by straight lines; that rubber stoppers, corks etc. may be indicated by crosshatching; that there should be no lines for the tops of open bottles, flasks, jars etc., inasmuch as these would not show in a cross section; that the plane should cut all essential parts; and that no shading should be used.

Laboratory drawings should also be well proportioned. The relative size of the various parts of the apparatus should be clearly shown. The drawings should indicate how the various parts can best be aranged so as to require a minimum of glass tubing, rubber connections, wire etc., to assemble them. This is primarily a matter for the teacher to illustrate in setting up his model apparatus before the class, but attention to it in the drawings made will serve to impress it upon the pupil's mind.

If it is granted that the ability to make plain, accurate, cross section drawings is very desirable, the means to be used in securing this ability merits consideration. The teacher in science will look in vain to the regular high school work in elementary and advanced drawing for much real help along this line. To secure satisfactory results the teacher must give supplementary instruction and training. It would be well to spend one or more laboratory periods near the beginning of the year in explaining how cross section drawings should be made and in training the class to make good drawings by actual work with some given arrangement of apparatus. The time thus spent will be more than regained by the increased efficiency shown in this respect during the balance of the year. Every new principle to be illustrated by apparatus in the laboratory should be developed in the classroom first by the use of a good sectional diagram on the board explained before the class by the instructor. Results will be best if the instructor skilfully builds up this drawing as he explains the construction. The drawing should evidently be made in the order in which the parts would be assembled or the instrument studied in the laboratory. In addition to board work by the instructor, much free-hand sketching on the board and upon paper should be done by the class.

Another helpful device is indicated in the title of this paper. Sets of sectional drawings may be drawn or printed upon cardboard, so that one can be placed in the hands of each student. For these drawings heavy white cards of uniform size, perhaps 5 by 8 inches, should be used. Upon these should be printed in firm black lines cross section diagrams of all the important machines and pieces of apparatus in common use, one diagram only being printed on each card. The diagrams should be carefully lettered, using so far as possible the initial letter of the name of the part. When apparatus illustrating a new principle is to be taken up, the class should be supplied with these cardboard diagrams and the subject developed by use of a large drawing on the board or by a large wall chart similar to that in the pupil's hands. As the cardboard drawings would necessarily be much larger than those in any textbook, they would be correspondingly easier to understand and to remember. Various means will be readily suggested for clinching the facts shown in the drawings and for fixing in mind the essentials of the drawings themselves. It would be helpful if a series of this sort could be published by some of the scientific houses at such a price that they could be supplied to each pupil in our science classes.

It may be suggested in closing that whenever we find that our students have inaccurate notions in regard to certain apparatus and its purpose, it will be well for us to determine whether we are teaching them how to draw what they study. In many cases some systematic work along the lines indicated above will be found very beneficial in clarifying and strengthening a pupil's knowledge.

Section B — BIOLOGY

WHY ARE THE IDEALS OF BIOLOGY TEACHING NOT REALIZED?

A. G. CLEMENT, STATE EDUCATION DEPARTMENT, ALBANY

A well known teacher of biology recently said that the papers read at the last meeting of this association contained all the essential points to be observed in the teaching of this subject. After referring to those excellent papers I was quite disposed to agree with him. Some of the ideas advocated therein have been presented in one form or another at nearly every meeting of this organization. Let us briefly indicate them. Over and over again it has been declared that students should be taught to observe carefully and to express accurately the results of their observation; that their culture should be increased by enlarging their outlook on the world and its phenomena, in order that they may comprehend the relation and interdependence of plants, animals and man, thus developing new interests which would tend to make their lives more useful and happier; that they should be taught how to care properly for their bodies in order that health may be preserved and the ability to labor assured. It has also been maintained that it is the function of this study to stimulate the imagination, to teach the truths concerning life, to strengthen the intellectual and reasoning faculties and to create high ideals.

Of the advanced courses more is required; these in addition are expected to develop the idea of evolution, division of labor and the struggle for existence. The remarks in this paper, however, are intended to apply specially to the first year course in biology as formulated in the syllabus of the Education Department of this State.

That the subject as taught in the high schools does not yield the results desired, I know from observation of the laboratory work, from the answers given by students when questioned in the classrooms, from examination of their notebooks, and from the way in which certain fundamental principles are often explained in the answers given to questions set by the State board.

Since the ideals of this course have been presented so often and so carefully, it seems pertinent to inquire why they are not more fully realized in teaching. In seeking for the causes that make for the success or failure of teaching this subject, there are at least four human factors to be considered, viz, the men representing the school district as a body politic, usually known as the board of education, the parents or guardians of the children, the teachers, and the children themselves.

In discussing the influence of these factors it should be recognized that the conception of the meaning of biology, as a branch of study, has not yet become well defined in the minds of the public. It is looked upon only as another name for teaching botany or zoology or physiology as such, in accordance with the old methods of teaching these branches, rather than as a subject having an educational value of its own. Some teachers seem to entertain this idea and instruct largely from the point of view of structure, often studying only lifeless forms or sometimes, relying on textbooks and using no specimens. Such seem to overlook the fact that biology is a science of *living* things, and teach as though it were a science of *lifeless* things.

The first year course in biology emphasizes processes, regarding the subject from the point of function. This necessitates the study of living organisms. If animals and plants are to be studied as living organisms, it follows that schools must provide an environment suitable for their growth, care and comfort. This brings us to a consideration of the first factor responsible for the nature of the teaching, the school district, as a body politic, represented by its board of education or trustees. The district has done its part when it has contributed freely to the needs of the school for teaching a subject in a proper manner. It would seem that most boards of education, through ignorance or parsimony, fail to arrange and equip laboratories in such a manner that animals and plants can grow, develop and have their being. They are not yet willing to provide an animal room with cages and aquariums and a small conservatory well lighted and heated in which plants can grow and mature; as a matter of fact four fifths of the laboratories now used are not provided with facilities for preserving a temperature in which seedlings can live through a cold night, unless the whole building is kept at the same temperature. In extenuation of allowing students to draw from pictures, rather than from nature, teachers often say that their specimens froze. For the best teaching of biology it will not suffice if plants or animals are observed only in a single phase of growth; they should be observed from day to day and records made of the changes in the organisms as they develop, whether the objects studied are bean seedlings or tadpoles, corn seedlings or caterpillars. Then the studies become really interesting and absorbing.

The comparative method is the true method of biology. The teacher used the right method who required her students to collect caterpillars and care for them, observing and recording the changes that took place as the creatures gradually wove their cocoons and passed into a resting stage, emerging from their long sleep as beautiful butterflies. In order to secure good results laboratories must be kept at a temperature high enough to sustain plant and animal life for a period of time longer than a day or a week. Not until boards of education will equip laboratories for teaching biology as adequately as they do for teaching physics, will this subject be taught so as to realize the ideals set forth in papers read at former meetings of this association. The first reason then why the ideals of biology teaching are not realized is because boards of education fail to provide the conditions requisite for satisfactory work.

The parents or guardians of the children are a second factor responsible for the nature of the instruction. Having been educated under a régime that demanded the study of books rather than of things, they deride the study of insects, earthworms and frogs and sometimes object to the inculcation of habits of hygiene and cleanliness. Their attitude reacts on the minds of the children and causes them to lose interest in the subject. This is a second reason why the ideals are not realized.

The third factor, the teacher, is generally held responsible when good results are not accomplished. This is not always fair, specially when, as in most cases, boards of education and parents have not done their duty. Yet, even with the best equipment and the closest cooperation of parents, the ideals of biology teaching will not be attained if the work is in charge of inefficient teachers. There are teachers well qualified who do the best work possible with a limited equipment, and there are those who fail, because they go before their classes without a well defined plan of presenting the topics under discussion. There are also good teachers who are burdened with three or four other subjects, algebra, English, history etc. so that they are unable to concentrate their energies and, of course do not secure the best results. Again, there are teachers who assume to give instruction with little or no preparation, relying on their ability to prepare the subject from day to day. It seems needless to say that these invariably fail. Some industrious teachers fail because they do not early in the course give the right point of view. They pay too much attention to structure, when they should emphasize function; they fail to give demonstrations showing the nature of fundamental processes common to plants, animals and man; they do not clearly teach the relation and the interdependence of plants, animals and man; they teach physiology, botany, and zoology as separate branches instead of correlating the subject-matter in such a way as to make the students see the unity of these branches and thus gain the biology point of view. The third reason then why the ideals of biology are not realized is because many teachers do not present the subjects in such a way as to interest the students and gain their attention.

The last factor to be considered is the children. It seems needless to say that they will always become interested if the subject is properly taught. If teachers persist in presenting the three principal phases of the subject as though they were three distinct and separate branches of study, the children will not grasp the ideals of biology teaching. For first year students an elementary course in biology creates more new interests, gives a better training, brings a wider outlook on the world and its phenomena, and tends to develop a broader culture, than a year course in either botany or zoology or physiology.

To recapitulate, the reasons why the ideals of biology teaching are not more fully realized are because the course is not presented as a unit with proper correlation of its various phases; because some teachers are not well prepared for the work or are not allowed to give adequate time to the preparation and presentation of the lessons; because parents do not recognize the value of the study of living organisms and, because boards of education fail to provide well equipped laboratories. When conditions are improved, the children will show their appreciation by grasping the ideals of the subject and embodying them in their lives and characters.

THE PRESENT AND FUTURE OF PHYSIOLOGY IN THE HIGH SCHOOL

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During the past several years in examining the notebooks of students about to enter college, in talking with pupils and teachers, in correspondence with various teachers throughout the State and in other ways I have been more and more impressed with the fact that the present teaching of physiology in the average high school of the State is not attaining the high ideal we would be glad to see, nor is it even keeping pace with the teaching of many other subjects of the high school curriculum in the development of the intellectual powers of the pupils.

The causes of this failure are numerous and arise, in some measure, at least, from a misapprehension of the nature of the subject to be considered. I am not so sanguine as to believe that you will agree with all that may be said in this paper, but it is my hope that you will agree that what is said is in a spirit of fairness and not of hostile criticism. It is not the desire of the college men to antagonize in any way the teachers of the high schools, but rather to work with them in building up within the borders of our commonwealth a system of instruction which shall render our boys and girls second to none in their ability to cope with life in all its varied phases. Any system which fails to add to the cultural, informational, and practical sides of our education fails to some extent in the work for which it was designed.

We have in the State of New York a requirement, so well known to you as only to need mention, that in the first year of the high school there shall be taught a minimum number of lessons of human physiology, a certain definite percentage of which shall be given up to the consideration of the effects of alcohol and other narcotics upon the organism.

Without discussing at this point the pros and cons of the temperance feature of the work, it is only fair to say that this requirement has not met with the enthusiastic support of the teachers of the State, whose cooperation is thoroughly essential to the satisfactory application of the law in question. That temperance instruction in the schools is imperative may be accepted as a fact that needs no further demonstration, but whether the course in physiology, with its limited time and great ground to cover, is the place for it is a question worthy of serious consideration. By the time the pupil has arrived at the high school, he has had poured into him during his stay in several grades more or less of the facts of human physiology. These graded studies have been presented in many cases, in a perfunctory manner, by teachers whose knowledge of the subject is bounded by the covers of the book used.

The statement just made may seem harsh, but that it is accurate beyond question there is no possible doubt. Under such conditions it is not difficult to see that the teaching, whatever the intention of the teacher, will be lacking in that directness and inspiration which have so much to do with the proper direction of the minds of the pupils. The work is of necessity very largely a matter of repetition. The same facts are gone over time after time, the language of the book is the language of both pupil and teacher alike, and in both instances likely to be the mere pronouncement of words rather than the expression of live thoughts. Few new facts are discovered, few new ideas are gained, old thoughts wear the same clothes day after day and term after term. Is it to be wondered at that the pupils can not understand why they are required to repeat so often the nauseating dose, or that they have an attack of brain fag at the time the class in physiology is called?

Now not all teachers are of the type which has been described. There are those whose work is thoroughly and conscientiously done. I can recall with pleasure the teaching of a certain woman who taught for the pleasure of teaching, the pleasure of seeing the young mind grow under her direction, and not from any mercenary motive. Under her direction I learned a few facts that have stuck through the years that have passed, but they have remained because she made us see that she knew whereof she spoke and was not limited in her knowledge by the pages of the book.

When the pupil comes into the high school he finds that he is obliged to take another does of a medicine that has already become distasteful. His human nature revolts, in many cases, and he attempts to slight the work. So a bad matter becomes worse. These facts have been brought out through inquiries made in various quarters and may be accepted as true, even though not flattering.

Many high school principals and teachers have come to regard the work in physiology as somewhat of a farce. And I take it that this attitude has not been assumed on account of any desire on the part of the teacher not to do the thing that is best for the student, but rather because they as teachers have been required to do a thing which is practically impossible — namely, to teach a subject at a time and in a place in the curriculum where it does not belong.

They have made the attempt, and have met with a lack of success which has led to discouragement, with its attendant evils. Long ago the colleges of the State refused to accept physiology as an entrance subject and, for the reason that in their opinion the work was not of the same high grade as that of the other subjects which were presented for entrance to college.

In making these statements I am not seeking to place the blame upon the teacher, for it is my firm conviction that the fault lies rather with the system which requires a teacher to attempt the impossible, and with the school board which encourages the young and inexperienced teacher to believe she can do a thing for which she has not pretended to make any adequate preparation.

There is no question that the teacher of physiology needs special training in order to be prepared to do the work in a proper way. A single instance showing the attitude of the authorities of the school toward the subject will suffice. In the school in mind only so much physiology is taught as is necessary to meet the legal requirement, and this not in the form of well connected lessons requiring some attention on the part of the pupils but as a series of isolated experiments, without previous instruction as to the meaning of the experiment, or any subsequent discussion as to the application of the principles involved.

The kind of physiology taught in the high schools is doubtless one of the sources of the lack of interest. School boards and even some principals have been content to consider anything as physiology which has to do with the functions of the body. A variety of textbooks has been put upon the market by enterprising publishers. Some of these have in them much of good, others much of harm and actual inaccuracy. Certain texts have been unable to make a place for themselves in the schools because they have failed to pass the censorship of the Women's Christian Temperance Union, when as a matter of fact they are far better books for school use than others which are accepted. School boards have been preyed upon and have been induced to introduce the book of some certain house without attempting to discover whether the lower price of the book chosen was in any way related to the quality of the material contained therein. In many cases the school boards have no doubt acted in perfect innocence, as well as ignorance. In other cases there is the intimation that undue influence may have been employed to bring about the end in view.

Another factor in putting the teaching of physiology upon the level where it is at the present time is the attitude of school boards upon the compensation which should be received by a teacher and the amount of class work that the teacher should be called upon to do in order to hold a certain position. It is perfectly absurd to think that a teacher can teach a half dozen different subjects to large classes, conduct laboratory work involving the collection and preparation of material, the setting up of apparatus etc., examine notebooks, correct exercises of one sort or another and do all as well as it ought to be done. If the teaching is worth doing at all it is worth doing well, and it can not be done well when the teacher is overburdened by work.

The teacher for any given course should be chosen because of fitness for that particular work, and should not be required to sacrifice her own self-respect and the best interests of the pupils by attempting to teach a subject which, from her own confession, she is unfitted to undertake. I have personal knowledge of more than one teacher in the State who is doing work for which she does not claim to be prepared, and simply because it has been forced upon her. You may say that she ought to refuse to do the work. Perhaps so, but she would answer that the call for life is stronger than the sense of duty she feels toward her fellows. I have no doubt at all that that very reason would be given in many cases if a reason were called for.

The manner in which the course is conducted in the various schools is another reason for the varied results obtained. In some schools the subject has been taught simply as a text subject, without either laboratory work or demonstration. As such the course has not been able to meet the needs of the pupils. In other schools there has been a combination of text and laboratory work under the guidance of a teacher with scientific impulses and training. Here the results have been of a kind to indicate that if physiology is not a success in the high school it is not entirely the fault of the pupil. Is it not time that we as teachers of science should see to it that the teaching of our courses should be of the highest order attainable? I wish to enter a protest against the teaching of any subject in a half hearted or inadequate way. And I do this on account of the moral effect of the teacher's attitude upon himself and upon the pupil. The high school pupil is a human being with well developed powers of discernment — along certain lines. Any pretense or bluff on the part of the teacher is recognized by the pupil as readily as by the teacher and results in the loss of confidence and respect for authority which must exist in the school if any work of permanent value is to be accomplished.

During the past 10 years there has been much done toward a reorganization of the science courses in the high school. The courses in chemistry and physics have received most careful attention and at the present time these subjects are presented in very many of the schools of the State in a thoroughly dignified, honest, scholarly way. Those who have been instrumental in bringing about these new courses of study are to be congratulated upon the results of their self-sacrificing labors.

There has also been an attempt made during the past few years to reorganize the work in biology. The first year course outlined in the syllabus together with the courses in botany and zoology form the basis of the work done in the schools of the State. The way in which these different subjects are treated in the different schools of the State is very interesting. Some schools now offer a full year of botany in addition to the first course, some a full year of zoology, some a half year of each, and some no work beyond the first course. The conditions under which different schools are working will account for some of this difference, and yet it is apparent that the variation in the amount, and, I think, the quality, of the work is much greater than would be found in either chemistry or physics.

There is also a difference of opinion as to the teachableness of the first year course as it is now laid down. Some teachers have expressed to me their great approval of the course, saying that they have met with great success in their teaching, that the interest shown by the pupils was beyond their hopes etc. Others have expressed the opposite view and have said that they did not understand how one could hope to do much with a class under the present conditions. It is evident that there are two sides to the question.

There are some things that can be said of the course. It is at present a three headed subject, botany, zoology and physiology. As such it is a misnomer to call it biology. The course is lacking in unity, and if there is any place in the high school course where a well unified course is needed it is in the first year. I can readily understand that a well equipped teacher could cover the points laid down in the syllabus and give a logical, scientific course in biology. And I can further understand that another teacher lacking in training could cover exactly the same points and leave the pupils in a maze of bewilderment which would forever destroy in them any taste for things biological.

One question which should have consideration by the teachers of biology of the State is whether, in the reorganization of the courses in biology, physiology should have any place. What claims can the subject present which those in charge of our biological destinies shall be bound to respect?

1 Physiology is a science, broad and general. The time has not been so very long in which we have been able to make that statement truthfully. But we are now at a time when we can say that we do have a fund of knowledge of the functions of the living organism gained through systematic observation, through experiment, and which is properly arranged and systematized. The method of physiology is scientific. Certain facts are observed. From these facts, properly related to each other, we are in position to draw certain conclusions concerning the fundamental properties of living matter, or deduce the laws that control the actions of the animal under certain definite conditions.

2 Physiology is a general science, and so has a claim upon our attention. In our weakness and narrowness we are accustomed to apply the term only to the human and so refer to a very circumscribed field. The subject is as broad as life itself. Living matter of every sort and description comes within its bounds. So long as we deal with the actions and functions of the living substance we are dealing with physiology pure and simple. When we limit our subject to the actions and functions of one animal and that a very much specialized one, we are losing some of the breadth of view and some of the scientific inspirations which come from the consideration of life in its more varied forms. It is sometimes hard for the teacher to remember that function is the fundamental thing instead of structure and to remember to ask the question how does the animal do this or that thing instead of " what is this structure for?" With the breadth of view involved in the more general study comes a new idea of the vastness of life and the value of life as well. Physiologists have been accused of lacking a proper respect for the value of life. My own experience leads me to say that the man who has the greatest respect for life is the man who has come nearest to the secret of what life is and knows better than any one else the greatness of the mysteries locked up within the compass of the living cell.

3 Physiology is coming more and more to be classed as an exact science. As a science it is young. The one great reason for the snaillike pace of the development of the science is that men did not

for a long time realize the importance of giving to it the same painstaking care and thought they were willing to give to the other sciences. This attitude arose in part from the fact that the explanation of the acts of the living organism was thought to be beyond the grasp of the mortal mind. Even the medical colleges have been greatly at fault in this regard. We are now beginning to see that the living substance does give rewards for careful observation and that the answers to some of the questions put are really more uniform than some have professed to believe. We no longer feel that the functions of the protoplasmic cells are entirely beyond our ken. It is becoming more and more possible to predict with certainty what a given cell will do under definite conditions. We are beginning to find out how the cell goes to work to do some of the things that form a part of its daily work. There are other things that we do not know and may not for a long time to come. The fact that we do not know, however, no longer makes us feel that we can not, but rather encourages us to press on to find out some of the things that are just at our hands waiting to be picked up and made of use.

We are beginning to recognize in the activities of the cells of our bodies the workings of some of the forces of physics and chemistry with which we are already acquainted. We are learning to apply the knowledge gained in other branches of science to the problems of the living cell, and with considerable success. We are beginning to put cells and tissues to the tests of physical and chemical laws and are finding out that some of the things we thought of, not so very long ago, as belonging to the realm of the mystical and the unknowable are really explainable after all. It is not my wish to convey the impression that we are likely to solve all the mysteries of life in the immediate future, but simply to make it clear that we are making progress of a very satisfactory sort.

There are comparatively few fundamental processes to be considered in the study of the living organism and these are all of a type which require previous definite knowledge along physical and chemical lines. Some of our teachers have recognized this fact and have included in the first part of the course in physiology a series of experiments in physics and chemistry. These have served in a way to give the student somewhat of an idea of what a reaction is, but they have been simply a means to an end and can not be considered as in any respect an adequate preparation for the work which is to follow. So if physiology is to mean anything to the student he must have had a course in physics or chemistry, preferably the latter if only one be possible.

Another fact needing consideration is that before the student can have any adequate appreciation of the function of an organ or an organism he must be more or less familiar with the form and structure of the part under discussion. It seems to me a mistake to make the course in physiology so largely a course in anatomy as has been done in the past. The time is needed for the study of function and there is plenty to take all the time available without making any elaborate structural study in the course. It will of course be impossible to cut out all matters of structure, but they can be trimmed down very much to the betterment of the course. The typical structure of the animal body can be gained in the study of zoology, or in the first year course in biology, if that shall keep its place in our curriculum.

You will say that I am making demands which are impossible to meet. I contend that it is the subject that makes the demands and not the writer of this paper. No one would think of teaching algebra to a pupil before he had been instructed in the elemental processes of arithmetic; no more should an attempt be made to teach to a student the functions of a living body before he is in position to appreciate the structures and physical and chemical principles involved.

It will be apparent from what has been said that if the physiology of the high school is to attain the ideal, or even approach the value of chemistry and physics as mental training, it can not be relegated to a small part of the first year of the high school course, but that it must have a place in one of the later years of the course, following the other subjects which have been shown to be prerequisite. By that preparation and that only is the student ready to enter upon the more complicated study of functions. Many will say that the upper years of the high school course are already too full. Perhaps they are — of things that need not be there. The high school curriculum must be arranged according to the demands of the subjects taught and not according to the desire of every teacher to have in his own classes the more matured and better prepared students.

Where in the course shall physiology be given? To my mind the course should be placed upon the same basis as the more advanced courses in botany and zoology and not made a part of a three headed course in the first year of the high school. Of course it is understood that legislative action would be necessary to bring about this change and that it could not be brought about in a minute.

It naturally follows that the course, if placed in one of the later years of the high school, can hardly be required of all students. There are many demands upon the time of the pupils and one could not expect a very large percentage of students to take up a subject for which the prerequisites are so great. Those who have real scientific, biological tendencies may be depended upon to find their way into and through a course thus placed.

What are the subjects which would demand attention in such a course? We must first, last, and all the time keep in mind the fact that we are dealing primarily with functions and not with structures except in so far as the structure makes the carrying on of the function a possibility. The structures are the mechanisms f carrying on the daily work of the animal. Inasmuch as the subject is broad we would attempt to discover the ways in which the different fundamental activities are carried on in a series of different animal groups. The work would then be comparative instead of special. For example we might consider locomotion as one of the activities of the animal. How is the locomotor movement effected in a number of animals? Consider the amoeba, paramoecium, hydra, a worm, a snail, crayfish, insect, salamander, fish, frog, man in this regard. The comparative study of this one function will give the student a new conception of cilia, muscle bands and skeleton designed to accomplish for these different animals, under dissimilar conditions, one and the same thing.

Under circulation we may take the same series of animals. First may come the question as to the necessity of a circulating medium at all. A comparison of the different forms will show the simplest forms of animals with no circulatory system at all; then a little higher up in the animal scale we find that the food matters are taken into a hollow bag and washed back and forth in order that all the cells forming the structure may have an opportunity to get a food supply. Then still higher up we find a definite blood system, but of low degree of complexity; the higher we go through the animal series the more perfect does the system become until we come to that of the mammal.

How is the taking up of oxygen and the giving off of carbon dioxid provided for in the different animals? Do animals really need oxygen? If so do all need an equal amount in proportion to size? What is the effect of the lack of oxygen? How is each animal adapted to his particular environment?

In a similar way may be taken up the different processes of metabolism — the mechanical features involved in food getting, the digestion of food either in the cells, as in the case of some of the lower animals, or in specially constructed tubes through the agency of enzymes, and then the absorption of the digested food through the wall of the tube, its transportation to the more remote parts of the body, and finally the building up of new protoplasm together with the removal of the waste.

We may also consider the ways in which animals come to an appreciation of things outside of themselves — the gradual specialization of the property of irritability as we pass upward along the series, until at the upper limit we come to animals having a number of well defined special senses, carrying in to the nervous centers messages which serve to direct conduct, give pleasure and promote the general welfare of the individual.

A topic not generally given the attention it deserves is that of reproduction. In the ordinary course in human physiology it is not easy to consider the topic in a way that is satisfactory. By making use of the comparative method it is not only possible but very natural to discuss the meaning of reproduction — to indicate the marvelous beauty and wisdom apparent in the method by which a race of animals is continued from one generation to another. Instead of being a subject tabooed and indicative of degeneracy it comes to be one of vast meaning and true sacredness, as the pupil learns the wondrous possibilities and mysteries locked up within the minute cell. I really believe that much of wrong thinking, wrong living, loss of health, and even of life may be avoided if we as teachers take the proper stand upon this matter and make the attempt to direct the minds of the youth along legitimate and proper channels.

How can all this be accomplished? I confess that the answer is not simple. That other teachers are asking the same question is certain; and that some are taking somewhat of the position as has been set forth is also evident from the fact that textbooks leading in the same direction are upon the market.

The textbook I should like to see has not yet appeared. If the teachers of the State give encouragement I have no doubt that the necessary text will appear. The laboratory outlines have also to be written. There are plenty who would be glad to undertake the work if there were any reasonable demand for such.

Laboratory study could and would form a large part of such a course as has been mentioned. The text work would be correspondingly reduced. The student would gain from his own observations a large part of the facts which would form the subject-matter of the course. In this way the work would become truly scientific, and would take its place upon the same plane as the other sciences of the high school course that have met with such signal success.

I can hear the teachers say "How am I to conduct such a course?" It will require work. It will mean previous planning. It may even mean that the teacher will have to do what many other teachers have already done — take the summer vacation for a course of study at one of the summer sessions of the colleges, or at one of the marine laboratories. I can imagine many fates worse than spending the hot days of July and August in the cool laboratories studying the activities of our little friends whose every move and act brings out something new and attractive.

RECENT PROGRESS IN ARTIFICIAL ILLUMINATION

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Mr President and Members of the New York State Science Teachers Association: When your president asked me to prepare a paper for this meeting which might be of general interest to all sections, I immediately thought of the subject announced to you. It was not until I began to prepare my notes, however, that I fully realized the great advance which has been made in this field in the last five years, and in order to keep within the allotted time, it will be impossible for me to more than mention some of these changes.

It is doubtful if many of us appreciate the vast interests which are centered in the production of artificial light. According to a recent article in the *Scientific American* the annual production of artificial illuminants in the United States is valued at $360,000,000, with an annual output of supplies of $180,000,000 more. These figures, amounting to over half a billion dollars, show us the vast interests which are involved, as well as the great prizes which are to be won by the inventor who puts upon the market a desirable form of illumination.

Before speaking of some of these improvements, it may be well to consider for a few minutes the principles of illumination in order that we may better understand the requirements placed upon the manufacturer. The human eye is so constructed that it can not stand the direct rays from a brilliant source of light but must have those rays coming to it from a point either above or behind the range of vision. Moreover these rays must be of nearly uniform intensity.

In order that comparisons may be made between different sources of light, some standard must be selected, and the one generally recognized is the so called "standard candle." The illumination from a standard candle at a distance of 1 foot is called a "foot candle" and the number of candles per square inch of the light-giving surface is called the "intrinsic brightness" of the light. This intrinsic brightness varies widely as seen in table 1.

TABLE I

[illegible] brilliances in candlepower per square inch (Bell)

[illegible]	600 000
[illegible]	500 000
[illegible]	2 000
[illegible]	10 000 to 100 000
[illegible]	1 000
[illegible] lamp	200 to 300
[illegible]	75 to 100
[illegible] light	20 to 25
[illegible]	3 to 8
[illegible]	3 to 4

To protect us from these strong lights, nature has furnished the eye with an adjustable diaphragm, which regulates to a certain extent the amount of light that is admitted to it. The attempt of the eye to shut out this brilliant light results in reducing the field of vision and making the surrounding areas appear darker, as may be noticed when passing along a street lighted by unshaded arc lamps. Diffusing this intense light by means of opal or ground glass shades allows the iris to open and, as more light then enters the eye, we can see better although the intensity of the light has been reduced. It might be noted in this connection that the way many students have of lighting their studies is wrong. There is usually a strong light on the desks while the rest of the room is in comparative darkness, and whenever the eye wanders from the brightly illuminated table it meets a strong contrast of light and shade which produces a strain upon the eye. The better way is to provide for a general illumination of the entire room and then in addition to have as strong a light upon the object as may be necessary for the work in hand. It has been found that reading and writing require less light than any other form of close ocular work on account of the sharp contrast between the type and the paper. A well printed book can be read comfortably with an illumination of 1 candle-foot while for special work like engraving the illumination should be as high as 5 candle-foot.

The laws of reflection are so well known as to scarcely make necessary a statement of them. The smoother the surface, the greater is the amount of light that is reflected from it in the plane of the incident ray, but as most materials do not have a perfectly smooth surface, the light is reflected at different angles giving what is called diffused reflection. It is such that we get from our [illegible]d walls and draperies. The amount of light reflected from [illegible]mmon materials is given in table 2.

TABLE 2

Amount of diffused reflection from common materials

White blotting paper	82%
White cartridge paper	80
Yellow wall paper	40
Green paper	0.18
Black velvet	0.004

Before considering the individual form of illuminants, it might be well to call attention to one of the comparatively recent improvements in lighting which involves the principle of reflection. I refer to the Holophane glass reflectors, samples of which you see before you. We have spoken of a light as of so many candlepower but this after all is rather indefinite for it says nothing of the direction in which the light is measured, so, in order that results may be comparable, it has been found convenient to distinguish whether the light is measured in a horizontal or a vertical direction or at some particular angle. A light measured in all directions is called the spherical candlepower and, in a horizontal plane, the horizontal candlepower. Since the light above the horizontal is of little value for most purposes, the value of a lamp is best rated by the light which it gives off in a hemisphere below the horizontal, which rating is known as the lower hemispherical candlepower. It is to increase this lower hemispherical candlepower of our lamps that the holophane reflectors are used. These shades are designed for different lamps and so are made in many styles but the common forms are of a bowl shape and known as concentrating and distributing reflectors, depending on whether most of the light is reflected on an area directly under the lamp or outward at an angle of about 45°. This is accomplished by means of prisms pressed in the glass at angles carefully computed from the size and kind of lamp and the direction of the object to be lighted. For these shades to work successfully, the lamp used with them must be of the style for which the shade was designed.

A concentrating reflector will raise the vertical candlepower of an 80 watt tantalum lamp from 10 to 110, while the light at 45° is 40 candles. The distributing reflector on the other hand will furnish 70 candles at this angle while the light below the lamp is about 55 candles or half that of the concentrating reflectors. This increased light is at the expense of the light in other directions and principally of the overhead light. The effect of these shades in increasing the illumination on an object is seen in these two blackened cabinets. (Demonstration) In one of them is a 16 candlepower electric lamp and in the other is an 8 candlepower lamp, and the difference in illumination on the placards below is quite apparent. If to the smaller lamp is affixed a concentrating reflector, its effect is instantly seen, or from an 8 candlepower lamp using 28 watts we are able to get more illumination than from a 16 candlepower lamp using 56 watts.

Within the last six weeks, further improvements have been made in the Holophane reflectors and there are now producd what are called extensive, intensive and focusing reflectors. The extensive reflector throws its maximum light at an angle of 45°, the intensive reflector gives more of its light directly under the lamp and a little less at 45°, while the focusing reflector will give practically all of its light directly below the lamp. (Demonstration) These reflectors are also made with three merging prisms instead of the continuous prism running from the narrow neck to the wide edge of the bowl. (Demonstration) This increases the lighting efficiency about 10%.

Turning now to the materials for illumination: The first which might invite our attention is acetylene. Time however will not permit me to go into any details. Acetylene has passed the experimental period and, while in my opinion it will never be used to any extent where gas and electricity are available on account of the annoyance of caring for the generator, it is destined to have an extended use for isolated buildings such as farmhouses and summer homes. The Canadian government is now using it extensively for marine lighting and the beacons off Point Judith, Sandy Hook and Cape Henry on our own coast are lighted by it. Within the last six years several hundred villages have installed central acetylene gas plants and the United States government has selected this form of lighting for its newest and largest army posts. A new form in which acetylene is now used is in solution in acetone. By this method, cylinders are filled with asbestos disks which are saturated with acetone and then acetylene is forced in under pressure. Compressed acetylene in this form is not explosive and is easily handled and this method is now employed with success for railway coach lighting. The New York, New Haven and Hartford Railroad has recently installed this system using cylinders prepared by the Commercial Acetylene Company of New York.

The Welsbach burner has been in use so long that it is not necessary that I go into any description of it. I will only say that in the last few years, great advance has been made in the life of the mantle by recognizing the importance of purity in the materials used. For instance, the cotton thread of the mantles must not contain over .015% of ash, which is one fifth less than in the best grade of medical absorbent cotton. There are before you a collection of samples showing the steps in the manufacture of the mantles. (Demonstration)

The impregnating or lighting fluid, as it is called, is composed of 99% nitrate of thorium and 1% nitrate of cerium. When the webbing which has been soaked in this material is heated, the nitrates are changed to oxids which retain the form of the cotton webbing that has been burned away. It is interesting to note that either of these oxids alone has but a moderate lighting power, and any proportion varying slightly from the one given causes a marked reduction in the lighting power of the mantle. Mr H. S. Miner of the Welsbach Company has kindly prepared for me ten mantles of varying composition, ranging from that of pure thoria in no. 1 to 90% thoria and 10% ceria in no. 10, as shown in the following table:

1	Pure thoria		7	candlepower
2	0.25%	ceria	56	"
3	0.50%	"	77	"
4	0.75%	"	85	"
5	1.00%	"	88	"
6	1.50%	"	79	"
7	2.00%	"	75	"
8	3.00%	"	65	"
9	5.00%	"	44	"
10	10.00%	"	20	"

On lighting these burners you will at once see the difference in the illumination of the different mantles and observe that the one with the above mentioned proportion is the most brilliant. (Demonstration)

The Welsbach light is a steady, high power, efficient light. It consumes about 3.7 cubic feet of gas an hour producing about 63 mean spherical candles. At one dollar a thousand, this lamp will furnish about 170 mean spherical candles for one cent against 42 for the open tip burner. The chief drawback to it is its color. Three or four years ago there were introduced for use with Welsbach burners what have come to be known as air-hole chimneys and shades. The principle involved is that more air can be admitted around the base of the mantle than by the usual openings in the burner which allows the consumption of more gas and hence a higher temperature and a stronger light. In the better grade globes, the holes are made by fusing the glass at the spot by means of a blowpipe, while a cheaper grade is made by blowing the globe in a mold having pockets for the formation of "bosses" which are afterwards ground off. These types are seen in the specimens before you. This air-hole glassware is very popular where strong lights are desired as in store illumination, but it must be remembered that this increased brilliancy is secured by the sacrifice of efficiency for the increased consumption of gas more than offsets the gain in light.

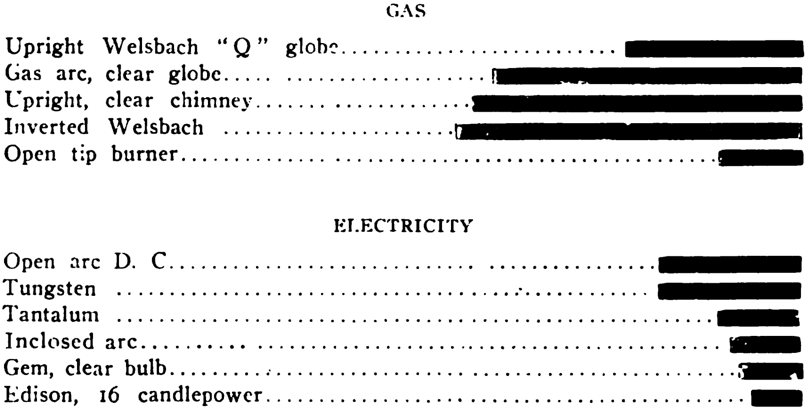
The efficiency of the Welsbach mantle suggested the grouping of several into clusters for large candlepower units and four years ago there were placed on the market what are known as gas arcs. The lamp consists of four mantles mounted on four burners, the whole inclosed with an opal shade and fitted with a metal hood; in appearance it resembles an electric arc lamp. They are equipped with pilot lights so that the light can be turned on or off by the single pull of a chain. (Demonstration) The lamp is a high power unit, its mean spherical candlepower being about 225, which is about the same as that of an electric open arc lamp. It consumes 19 cubic feet of gas per hour and its efficiency is rated as 12 candlepower per foot of gas consumed. These lamps are a very economical large unit light.

Within the last two years, there has been perfected what is known as the inverted gas lamp. In principle, this is the same as the usual mantle lamps, but the mantle is placed below the burner, which results in a greatly increased downward distribution of light. You who have worked in the laboratory know how badly the ordinary Bunsen behaves when it is turned upside down. Like the upright burner, the inverted depends for its success upon the proper regulation of air and gas, but in the latter the proportion between the air and the gas changes gradually after being lighted, due to the heat radiating upwards around the intake of the air. To obviate the necessity of adjusting the air supply every time the burner is lighted, there is inserted in the tube what is known as the thermostat. This is a cone-shaped cylinder made of two metals of different coefficients of expansion, and which when cold prevents too much aeration, but upon becoming warm opens and allows a larger proportion of air to mix with the gas. (Demonstration) It is this thermostat which makes the inverted burner possible.

The inverted gas lamp consumes 3 cubic feet of gas per hour against 3.7 cubic feet for the upright. It has a mean *lower* hemispherical candlepower of 70.6 against 51.3 for the upright and an efficiency of 23.5 against 13.0; or put in another way, 1 cent will buy 235 mean lower hemispherical candles in the inverted and 138.5 in the upright burner, or it is 70% more economical. It is not surprising then that the upright Welsbach is rapidly being replaced by the inverted and that the manufacturers expect in a few years that all burners of the incandescent system will be of the inverted type.

At the average prices prevailing, it is the most economical source of household illumination that we have as shown by the following comparative scale:

COMPARATIVE AMOUNT OF M. S. C. P. TO BE OBTAINED FOR 1 CENT AT $1 PER THOUSAND AND $.10 PER KILOWATT



Inverted gas arc lamps are already on the market and one is promised by the Welsbach people at an early date.

About five years ago, there appeared in Germany what is known as the flame arc lamp. This lamp grew very rapidly in popularity and today 95% of the exterior lighting of Berlin is by these lamps. Somewhat over two years ago this lamp appeared in this country, and though its popularity here has not been as great as abroad, it is being quite widely installed. These lamps are easily recognized by the soft though powerful yellow or orange color which they give and by the long metal casing of the lamp. In these lamps, the positive or hottest carbon is either impregnated with, or has a core running through it, of salts consisting chiefly of calcium and potassium fluorids with boric acid as a steadier. In the arc these salts are gasified and, besides giving a characteristic color to the flame, the vapors act as a conductor for the current and make possible an arc three or four times as long as the ordinary one. In order to prevent this large flame from flickering, it is necessary to make the carbons of smaller diameter and, since such carbons burn up rapidly, it becomes necessary to lengthen them in order to get an all-night lamp. Since this excessive length of carbon increases the resistance materially, the manufacturers have tried inserting metallic threads in the electrodes, or coating them with copper, in order to reduce the resistance. (Demonstration) The salts in the carbons gave rise to a flux on the tip which sometimes produces an "outrage." To obviate this difficulty; the lamps are constructed with the carbons inclined like a capital V to a point below the mechanism. This allows the flux to drop from the tip and also does away with any obstruction of light by the mechanism as is the case in the open arc lamps. This arrangement results in the maximum light being directly under the lamp instead of at an angle; consequently for street lighting, these lamps are placed at elevations of 30 or more feet. The lamp requires 45 to 50 volts which allows two being installed in series on a 110 V circuit. It has a mean hemispherical candlepower of 1500 with an efficiency of about one quarter watt per candle and is the most efficient form of electric lighting that we have. The chief drawbacks are the cost of maintenance, which amounts to 20 cents per lamp for carbons and trimming for an all-night lamp, and the vapors which they emit, necessitating outdoor use.

Another form of arc lamp using as electrodes substances other than carbon is the magnetite or luminous arc lamp. (Demonstration) This lamp has as a negative electrode a copper rod ¾ inch in diameter incased in a 1/16 inch iron sheathing, while the positive electrode is made up of a mixture of approximately 60% magnetic iron oxid, Fe_3O_4, 27% titanium oxid, TiO_2, and 13% chrome iron oxid, $FeCr_2O_4$. The iron oxid makes the mass a conductor, the titanium oxid gives it its brilliancy and the chrome iron oxid acts as a steadier. The copper electrode is consumed at a rate somewhat less than 1/16 inch per 100 hours, while the positive mixture lasts about 200 hours. These lamps therefore do not need trimming oftener than once in two or three weeks. As this makes the cost of maintenance low, this style of lamp is popular with American lighting companies. At the present time, the Lighting Company in Syracuse is engaged in replacing its old open arc lamps with this form.

The Nernst lamp was formerly used on the alternating current only. This has been improved within the last two years so that it is available now for both alternating and direct currents, which doubles its field of usefulness. On the first of last September, a new form of the lamp bearing the name of the Westinghouse Nernst lamp was placed on the market. In this new form, the composition of the incandescent body called the "glower" has been improved by the addition of the oxids of certain of the rarer metals, the names of which have not been made public. A 132 watt single glower type gives a mean lower hemispherical candlepower of 114.8 with an efficiency of 1.2 watts per candle against 2.05 for the former type. This is a gain in light of 41.5% for the same current consumed. The life of the glower is given as 600 to 800 hours. The lamp has also been improved in its mechanical construction and the bulbs may now be removed from the fixtures in the same way as the incandescent carbon bulbs. With these important changes we are likely to see more of these lamps in use in the future than we have in the past. (Demonstration)

In the ordinary electric lamp there is a great amount of energy absorbed by the solid conducting medium which fact has led to attempts to use incandescent vapors and not solids as the source of light. The Cooper-Hewitt lamp is constructed on this principle. Here the current is conducted by the vapor of mercury through a glass tube about 30 inches long and 1½ inches in diameter. Its intrinsic brightness is low, being about 19 against 200 for the incandescent lamp. The great objection to the lamp is the color which it gives to the objects seen by it, as you will perceive by examining these colored tissue papers. (Demonstration) In order to start the original form of the lamp, it was necessary to tilt the tube by means of pivots set near the center. This was awkward and the current was not always established the first time. This decided disadvantage has been overcome within the past year and the company is now marketing two forms of lamps, one of which is tilted automatically by means of a solenoid and shunt, while the other and more improved form is constructed with a so called shift which, by producing a high potential across the tube, starts the lamp without the necessity of tilting the tube at all. Whereas two years ago the Cooper-Hewitt lamp could be used only with the direct current, it is now available for the alternating current as well. This lamp gives about 800 hemispherical candlepower for the 50 inch size with a commercial efficiency of approximately .5 watts per candle and ranks next to the flame arc lamp in efficiency. It is especially easy to the eye on account of its low intrinsic brightness and although the color is bad, as has been stated, it has found a large field in the lighting of mills, machine shops, foundries or wherever color is of the least and efficiency of the greatest importance.

Another form of light using gaseous or a rarified form of gaseous conductors is the system known as the Moore light. The light is that emitted by an electrical discharge through a partial vacuum. The system consists of glass tubes about 1¾ inches in diameter and of any length desired up to several hundred feet. These tubes are built up of short sections fused together by a blast lamp after being cut and bent to fit any position. It is, in short, a system of "glass plumbing." The usual position for the tube is to circle the room a few feet from the walls and about 18 inches below the ceiling. The two ends of the tube enter a slate box where the terminals from the mains are fused into them. A vacuum of .1 millimeter of mercury is effected by a pump and when the current is turned on, the tube emits a soft even light throughout its entire length. This light would continue but a short time however, were it not for a special feeding valve. It is an experimental fact that while an electric discharge may be sent through a vacuum of high degree there is reached a point when the current ceases to flow, and moreover, as a current passes through the vacuum, it somehow, in a manner not satisfactorily explained, uses up the vacuum, if such an unscientific expression may be allowed, and, after a short time, the light goes out. In order to keep the light constant it is necessary to feed some gas into the tube in just sufficient quantity to prevent the stoppage of the current. It is this point that is the successful feature of the Moore light. A small feeder valve operated by a solenoid causes a drop of mercury to rise and fall around a small ¼ inch charcoal plug placed in the opening of a small tube feeding to the main tube. As the charcoal plug becomes uncovered, enough air filters through it to give the necessary conductivity within the tube, and, as soon as a sufficient amount has entered, the current through the solenoid is broken and the mercury drop covers the charcoal plug again. In normal working the charcoal tip is exposed about one second a minute and the movement of the valve is not more than 1/32 of an inch. If the gas admitted to the tube is air, the color of the light is of a pinkish shade, but if the oxygen is first removed by passing air through cylinders of phosphorus, the color is changed to a golden yellow which is most efficient. If the tube is supplied with carbon dioxid, the color is pure white, and such tubes are in use today in the silk mills of Patterson for matching colors since the spectrum always remains constant. The tubes operate on a 220 alternating current, consuming from 1 to 1.5 watts per candle. (Demonstration of photographs)

The temperature of the tube is not over 40°C., hence they are more comfortable in hot weather and safer at all times as there is no wiring to increase fire risks. The first cost of installation is no greater, it is claimed, than for properly wired electric systems with their necessary switches, cutouts and fixtures. Another great advantage is that the intensity of the light may be easily adjusted. The average candlepower per foot is 12 but it may be dropped to 6 or raised to 36 in which case the intrinsic brightness ranges from .33 to 2.00. When it is recalled that high intrinsic brightness is undesirable if the same amount of light can be obtained in an equally efficient manner, one of the advantages of the Moore lamp is apparent.

The carbon filament electric lamp is too well known to need any mention, except to say that carbonized silk and bamboo are no longer used but the filament is made by squirting soluble cellulose through fine holes. These threads are afterwards carbonized and then flashed by bringing them to incandesence in an atmosphere of hydrocarbons, which causes a dense deposition of carbon over their entire surface. About three years ago a decided advance was made in this lamp when there was put on the market what is known as the Gem or metallized filament lamp. This lamp is made in the same way as the carbon lamp but the filament is subjected to a further heating at about 2000°C. in an electric furnace. This insures the complete volatilization of impurities and leaves the carbon in its resistance similar to a metal, hence the name "metallized filament." There are on the table before you some specimens illustrating the steps in the manufacture of these filaments to which your attention is called, and there is burning here a finished 40 watt lamp and one of the carbon type of the same candlepower taking 56 watts for comparison. (Demonstration)

The color of the light is much nearer white than the carbon filament and it is also much steadier due to the fact that the Gem varies in candlepower only .7 as much as the carbon lamp, for each volt variation in potential. In efficiency it is a great improvement consuming about 2.5 watts per candlepower against 3.5 for the carbon filament. In table 3 are given some comparative figures showing the economy of this lamp over the carbon.

The development of the tantalum lamp is due to Dr Von Bolton and Dr Feuerlein of the Berlin Siemens & Halske Co. This metal is capable of being rolled and drawn into fine threads and it is in this form that it is used in lamps. One pound of the metal will make about 20,000 lamps. The conductivity of the thread is high, hence in order to get the necessary resistance, the length of wire in the bulb has to be considerably greater than in the carbon lamp, or about 25 inches against 9 inches. This necessitates stringing the wire on small glass arms for supports and as the wire contracts upon use, it is necessary to have it strung loosely at first. Such a fine filament is naturally delicate and has to be carefully handled though the lamps may be burned in any position. If a filament breaks, the lamp is not always rendered useless for if the ends be jarred into contact they will immediately fuse together and establish the circuit. The tantalum like the Gem varies but little with fluctuations in voltage. The melting point of the metal is high, about 2300°C., which allows a high temperature in the bulb and hence greater efficiency. At first these lamps could only be used on the direct current but they have been perfected within the past year so that they are now used on both the direct and alternating currents. Another advantage of these lamps over the carbon is that they do not blacken the bulb. The lamps are made in sizes of 25, 40, 50 and 80 watts with a rated nominal candlepower from 12½ to 40. The candlepower varies on use, increasing as much as 25% during the first few hours of life and then gradually dropping off, although this deterioration is much less than in the case of the carbon lamp. The efficiency of the lamp is about 2 watts per candlepower. As is seen in table 3, the energy consumption was reduced by the Gem lamp to 2.5 watts or a saving of 28% over the 3.5 watt carbon lamp. With the tantalum lamp, there is a further saving of 16% over the Gem and 40% over the carbon lamp. The cost of installing these lamps is greater, however, the price of a 40 watt lamp is about $.50 when bought singly, and lighting companies will not renew them free. Nevertheless it is cheaper to use these lamps. At any price above 2.2 cents a kilowatt, the use of the tantalum lamp is cheaper than the carbon, and at any price above 4 cents, it is cheaper than the Gem and as the cost of electricity is seldom as low as these figures to the average consumer, the advantage of the tantalum lamp is apparent.

The color of the tantalum lamp is white and colors appear in nearly their natural relations. (Demonstration) The intensity of the lamp is high and like the Gem they are usually made with frosted bulbs. The distribution of light from the lamp is not of the best since most of the light is given off at an angle, while directly below the tip the illumination is only about 5 candlepower, consequently these lamps are almost always equipped with holophane reflectors of some type. Improvements in this particular will be made in the near future without doubt.

The tantalum lamp had hardly had time to become known to the trade before the technical journals contained reports of a tungsten lamp that promised even better than the tantalum. This lamp was first exhibited at the Chicago Electrical Show in January 1907, and in June of that year it was first placed on the market. The output in this country at present is 75,000 daily and there are over a million American made lamps in use today.

The tungsten lamp like the tantalum lamp is a metallic filament lamp. The metal is exceedingly hard, but unlike the tantalum it is very brittle and can not be drawn into threads. Malleable tungsten is now being made at the G. E. Co. laboratories I am informed. It has a melting point of 3000°C. which allows its use at very high temperatures, and in keeping with all metals, it is a good conductor of electricity which necessitates the use of long filaments as in the case of tantalum.

Since the metal can not be drawn into threads, the filaments have to be prepared by other methods and there are three processes in use. Von Welsbach takes tungstic acid in a very fine state of subdivision, mixes it with a pasty binder and squirts it through diamond dies. Dr Kusel gets the metallic tungsten into a colloidal form which he concentrates to a gelatinous mass and squirts into threads. Dr Just and Hanaman prepare a cellulose filament in the same manner as for the carbon lamp. This filament is then flashed in an atmosphere of a gaseous tungsten compound probably the chlorid, which causes a deposit of the tungsten upon the carbon. The thread is next heated in an atmosphere of hydrogen which removes all the chlorin after which a second and higher temperature is used which volatilizes the carbon leaving the free metal in threads .03 millimeter in diameter. These threads are very brittle and require especial care in packing and shipping. The lamps work equally well on either alternating or direct current with an average life of 800 hours and an efficiency of 1.25 watts per candle. This is the highest efficiency of any of the metallic filament lamps, showing a gain of about 40% over the tantalum and of 64% over the carbon lamp.

For this reason, the lamps are recommended for use in a pendant position only and to be attached without chain pulls or socket switches. Nevertheless these lamps may be used in any position without much danger of breakage and may also be used with snap switches. A sharp knock, however, will usually break the filament, but like the tantalum lamp, the broken ends can be fused together and the lamp made serviceable.

I have here a lamp with a broken filament which you see can be made to burn by jarring the ends of the filament into contact. (Demonstration)

The brilliancy of the lamps requires the use of frosted bulbs unless they are to be placed well above the line of vision. The distribution of the light requires the use of holophane reflectors for the same reason as for the tantalum lamp. The quality of the light is a pure white. Shades of violet, blue, indigo and green as well as dark shades can now be matched by this light as well as by daylight. (Demonstration) It is this property as well as its great efficiency that has attracted so much attention to this lamp.

Another reason that makes the tungsten lamp interesting is the fact that it promises to make a revolution in street lighting. As has been stated, it works equally well on either alternating or direct current, and can be run in series of a large number of lamps to the circuit with an efficiency of 1 1/3 watts per candle and a candlepower of 40 to 60 or more. This means that instead of the brilliant arc light widely distributed, especially in outlying districts, circuits will be established with tungsten lamps placed near together resulting in a more even distribution of the light along the street.

These lamps are made at the present in sizes ranging from 25 to 250 watts with a candlepower from 20 to 200. They must be used with caution since they are large light units of high intrinsic brightness, and even with frosted bulbs are able to do serious injury to the eye if placed in the range of vision.

TABLE 3

Saving by use of high efficiency lamps

	Carbon	Carbon	Gem	Tantalum	Tungsten
Candlepower	20	20	20	20	20
Watts per candle (normal)	3.5	3.	2.5	2.1	1.25
Watts per candle (actual)	3.48	3.04	2.5	2.1	1.25
Total watts	69.6	60.8	50.	42.	25.

TABLE 3 — Continued

	Carbon	Carbon	Gem	Tantalum	Tungsten
Hours total life	1040	520	560	600	800
Cost of lamp (quantity)	$.16	$.16	$.20	$.38	$.65
Cost of renewals per 1000 hours	$.154	$.308	$.36	$.63	$.81
Cost of power per 1000 hours at 10c per kilowatt hour	$6.96	$6.08	$5.	$4.20	$2.50
Cost of power and lamp renewals per 1000 hours	$7.11	$6.39	$5.36	$4.83	$3.31
Saving over 3.5 watts per candle		$.72	$1.75	$2.28	$3.80
Saving over 3 watts per candle			$1.03	$1.56	$3.08
Saving over 2.5 watts per candle				$.53	$2.05
Saving over 2 watts per candle					$1.79

In table 4 are given the costs per hour and per candle per hour at Syracuse prices of some of the lights I have mentioned.

TABLE 4

Cost of lighting in Syracuse at $.95 per 1000 cubic feet for gas and $.08 per kilowatt for electricity

Candle-power	Watts or feet	Type	Cost per hour	Cost per candle per hour	Efficiency
8	28	Carbon	$.00224		
16	56	Carbon	.00448	$.00025	3.5
32	112	Carbon	.00896		
20	25	Tungsten	.002		
32	40	Tungsten	.0032	.0001	1.25
48	60	Tungsten	.0048		
80	100	Tungsten	.008		
200	250	Tungsten	.02		
240 (M. L. H.)	555	A. C. incl.	.044	.00019	2.3
2000	450	Flame arc	.036	.000018	.225
800	385	Cooper-Hewitt	.031	.000039	.48
18	6	Gas, open	.0057	.00032	.33
51	4	Welsbach	.0035	.000072	.073
70.6	3	Welsbach inverted	.0028	.00004	.042
396	19	Gas arc	.018	.000046	.05
480	16	Gas arc inverted	.015	.00003	.033
306	11	Gas arc inverted	.0105	.000031	.036

Among the proposals submitted by the Hartford Lighting Company recently, preparatory to renewing its contract for the city lighting, was one to use tungsten lamps, placing one on every pole.

There remains one other lamp to be mentioned which promises very well though not yet on the market; I refer to the Helion lamp. This is an incandescent lamp having a filament of silicon or a compound of silicon. It is reported as being made by flashing a cellulose filament in a gaseous compound of silicon, possibly the chlorid, contained in a receiver over mercury. The temperature of the flashing decomposes the compound causing the silicon to deposit on the carbon while the chlorin is held by the mercury. This deposited silicon has a resistance of about 50 times that of carbon, which allows the use of much shorter and heavier filaments than with any of the other forms of incandescent lamps and they are therefore much less liable to fracture from shock. The filaments it is stated may be heated to over 2000° without any blackening of the bulbs. The life of the lamp is not fully established but seems to be about 500 hours during which time the candlepower drops about 3%. The efficiency is reported as about one watt per candle which if it proves to be the case when manufactured commercially will make this lamp more efficient than the tungsten. What this lamp will really do in the commercial world remains to be seen but there is the promise here of a lamp that will bring the energy consumption down to one watt per candle and will not be fragile, and which can be made in units of all candlepowers. Two specimens of this lamp are here before you and you can see the color of its light and also the size of its filament. (Demonstration)

In conclusion, then, the last five years has seen the widely extended use of acetylene; the introduction of the incandescent gas arc and the inverted Welsbach; and the now general use of holophane reflectors. In the field of arc lighting, we have the flaming arc with its high efficiency and the magnetite lamp with its slow burning electrodes. There is the simplification of the means of starting the Cooper-Hewitt and its adaptability to the alternating current and the introduction of the Moore tube light. In the incandescent field there is the increase of the efficiency of the Nernst lamp by 40% and its adaptability both to alternating and direct currents; the change from the 3.5 watt carbon lamp to the 1.25 watt tungsten and possibly the 1 watt Helion lamp, with the great improvement in the quality of the light.

In the cabinets before you are two lights, each consuming approximately the same amount of current. They illustrate the progress of five years. At this rate of advance it is safe to predict that our present methods of exposed lighting will soon be replaced by diffused reflection, using concealed lamps of high power and efficiency, and the little incandescent carbon bulb will be gathered to its fathers.

MEMBERS 1909

Where no state abbreviation is given, New York is to be understood.

Aiken, J. Hawley, 3 Clinton pl., Saratoga Springs, High School
Allen, Harris C., Niagara Falls, High School
Atkinson, George F., Cornell University, Ithaca

Baker, D. L., Rome, Free Academy
Bailey, Guy A., Geneseo, State Normal School
Barker, Ernest F., 56½ Hamilton st., Rochester, East High School
Barrows, Franklin W., 1364 Michigan st., Buffalo
Barter, C. E., Malone, Franklin Academy
Beers, Everett J., 50 Lafayette av., Geneva, High School
Bennett, William M., 76 Wellington av., Rochester, West High School
Bentley, Gordon M., University of Tennessee, Knoxville, Tenn.
Benway, Mabel R., North Tonawanda, High School
Betz, William, Rochester, East High School
Bigelow, Maurice A., New York, Teachers College
Binns, Charles F., Alfred University, New York State School of Clayworking and Ceramics
Bishop, Irving P., Buffalo, State Normal School
Bogert, Marston T., New York, Columbia University
Bond, W. E., Potsdam, State Normal School
Boniface, Sister M., Rochester, Nazareth Academy
Bradley, Elizabeth L., Troy, High School
Brigham, Albert P., Hamilton, Colgate University
Brownlee, Raymond B., 345 E. 15th st., New York, Stuyvesant High School
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Woodhull, John F., New York, Teachers College

INDEX

Action, summary of, 9–14.
Agriculture, high school, by G. F. Warren, 21–28.
Apparatus exhibits, inspection, 39–41.
Artificial illumination, recent progress in, by H. Monmouth Smith, 115–30.
Auditing committee, report, 14.
Ayrton rheostat, modification of, 94.

Biology, 57, 100–30; why are the ideals of biology teaching not realized? by A. G. Clement, 100–3.
Biology syllabus, report of committee on revision, 9–12.
Bryant, Frank L., Relative Insolation Demonstration, 58.
Burgin, Bryan O., Demonstration of Dynamo and Motor, 90–92.

Carpenter, Harry A., Ionization Theory, 42–51.
Chemist versus the trained workman, by R. Livingston Fernbach, 65–70.
Chemistry and physics, 42–56, 65–99.
Clement, A. G., Why are the Ideals of Biology Teaching Not Realized? 100–3.
Clendenin, W. W., report of committee on resolutions, 13.
Council, report of, 13; members, 13–14.
Cross section drawings on cardboard for school use, by S. B Everts, 95–99.

Demonstrations, by Charles L. Harrington, 93–94.
Drawings, cross section, on cardboard for school use, by S. B. Everts, 95–99.
Dynamo and motor, demonstration of, by Bryan O. Burgin, 90–92.

Earth science, 58–61.
Electrolysis, ionization theory, 42–51.
Elementary schools, science course, discussion, 29–38.
Everts, S. B., Plain Cross Section Drawings on Cardboard for School Use, 95–99.

Federation with New York State Teachers Association, 14.
Fernbach, R. Livingston, The Chemist versus the Trained Workman, 65–70.
Fluorescence of fluorescent substances, method and apparatus for detecting and exhibiting, by Wallace Goold Levison, 52–54.
Forbes, Charles, Demonstration of Physical Apparatus, 71–76.

Gage, Simon T., quoted, 29.

Hanna, Jennie P., Hydrogen Sulphid Generator, 89.
Harrington, Charles L., Wireless Telegraphy, 55–56; Brief Demonstrations, 93–94.
Hawkins, L. S., on nature study, 30–34.
Heffron, John L., address of welcome, 15–19.
High school agriculture, by G. F. Warren, 21–28.
Hornaday, cited, 31.
Huxley, Thomas, quoted, 16, 17, 18.
Hydrogen sulphid generator, by Jennie P. Hanna, 89.

Illumination, artificial, recent progress in, by H. Monmouth Smith, 115–30.

Insulation, relative, demonstration, by Frank L. Bryant, 58.
[illegible]

Kenyon, [illegible]
[illegible]

Laboratories and apparatus [illegible] inspection, 29-31
Lee, Frederick S., letter from, 13
Lawson, Andrew Gould, Method and Apparatus for Detecting and Exhibiting the Fluorescence of Fluorescent Substances, 52-54
Lyon, Howard, on science teaching, 62-64

Map and modeling apparatus, demonstration of, 59-61.
Members, list, 131-38

Nature study, in elementary schools, 29.
New York State Teachers Association, federation with Science Teachers Association, 14
Nominating committee, report, 13-14

Officers elected, 13-14.

Physical apparatus, demonstration of, by Charles Forbes, 71-76; some practical apparatus, by William Timbie, 77-88.
Physics and chemistry, [illegible] 65-69
Physics syllabus, report of committee on revision, 9
Physiology, present and future in the high school, by Charles G. Rogers, 104-14

Relative insulation demonstration, by Frank L. Bryant, 58.
Resolutions, report of committee on, 13
Ring armature motor, small model of, [illegible]
Rogers, Charles G., Present and Future of Physiology in the High School, 104-14.

Science, reasons for teaching, 16; value as a means of mental discipline, 17.
Science course for elementary schools, discussion, 29-38.
Scott, I. D., demonstration of a map and modeling apparatus, 59-61.
Section officers, 14.
Sessions, summary of, 5-8.
Smallwood, W. M., report of committee on revision of biology syllabus, 9-12.
Smith, H. Monmouth, Recent Progress in Artificial Illumination, 115-30.
Some practical physics apparatus, by William Timbie, 77-88.

Teachers of Science and Mathematics, American Federation, recommendation that association join, 13.
Timbie, William, Some Practical Physics Apparatus, 77-88.
Treasurer's report, 14.

Vivisection, recommendations of council on, 13.

Warren, G. F., High School Agriculture, 21-28.
Wireless telegraphy, by C. L. Harrington, 55-56.
Woodhull, John F., report of committee on revision of physics syllabus, 9.

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